

Assessing Bilingual Knowledge Organization in Secondary Science Classrooms

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ABSTRACT

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Improving outcomes for English language learners (ELLs) in secondary science remains an area of high need. The purpose of this study is to investigate bilingual knowledge organization in secondary science classrooms. This study involved thirty-nine bilingual students in three biology classes at a public high school in The Bronx, New York City. Methods included an in-class survey on language use, a science content and English proficiency exam, and bilingual free-recalls. Fourteen students participated in bilingual free-recalls which involved a semi-structured process of oral recall of information learned in science class. Free-recall was conducted in both English and Spanish and analyzed using flow-map methods. Novel methods were developed to quantify and visualize the elaboration and mobilization of ideas shared across languages. It was found that bilingual narratives displayed similar levels of organizational complexity across languages, though English recalls tended to be longer. English proficiency was correlated with narrative complexity in English. There was a high degree of elaboration on concepts shared across languages. Finally, higher Spanish proficiency correlated well with greater overlapping elaboration across languages. These findings are discussed in light of current cognitive theory before presenting the study's limitations and future directions of research.

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Chapter I

INTRODUCTION

Right now, we find ourselves in a moment of incredible political and social upheaval. Issues such as race and income lie at the heart of much of the turmoil that we are currently experiencing. As a result, there has never been a more important time to conduct research addressing educational inequity. That is why my research focuses on English language learners (ELLs) in secondary science classrooms, an area of great need.

How far behind are English language learners in science? On a recent nationwide assessment of science achievement, average scores for ELLs in the eighth grade were lower than every other group as categorized by race, family income, or disability status (U.S. Department of Education, 2015). The majority of ELLs are represented by students of Hispanic origin, who have been the largest student-minority group since the 1990s, and are growing much faster than the nation as a whole (Chapa, 2006). According to the U.S. Census Bureau (2011), the Hispanic population grew four times faster than the national average and accounted for more than half of the country's total population growth from 2000 to 2010. This fast-growing demographic is dramatically behind in science achievement, and this threatens notions of both educational equity and economic progress in this country. Therefore, there is an urgent need for high-quality research that will inform the teaching and learning of science to English language learners.

A broad survey of the literature reveals that most research in bilingual education has focused on elementary students, largely ignoring the experiences of older bilinguals (August & Hakuta, 1997; Christian, 2001; Ruiz-de-Velasco & Fix, 2000; Janzen, 2008). Furthermore, advances in our understanding of bilingual cognition have seldom been applied to the science classroom. This dissertation study examines bilingual knowledge organization in ELLs. That is,

it looks at how bilingual students organize and recall information in either of their dual languages. An interdisciplinary study which builds on the most current understanding of bilingual cognition, it involves the assessment of knowledge organization when students recall science content in English and Spanish. Survey and achievement data are analyzed to examine how in-class use of the native language and varying proficiency levels relate to students' organization of knowledge in both languages. This should contribute to a better understanding of language development and content learning in the science classroom, ultimately benefitting recommendations of practice.

Chapter two provides a comprehensive review of literature from bilingual education, science education, and cognitive science. Chapter three articulates the theoretical framework and three primary research questions for the study. The methodology, results, and discussion are provided in chapters four through six. The thesis concludes with chapter seven, which summarizes key findings, implications for practice, and directions for future research.

Chapter II

LITERATURE REVIEW

Historical Overview

Bilingual education has a long and rich history in the United States. Ovando (2003) argues that this history has been shaped by “changing political, social, and economic forces, rather than any consistent ideology” (p. 1). Since the country’s inception, oscillating tendencies driven by expanding immigration and general xenophobia resulted in policies ranging from relative tolerance to linguistic repression (Ovando, 2003). However, these gave way to a stimulus in foreign language education catalyzed by the *Sputnik* space race and the 1958 National Defense Education Act, which provided funding for teachers of foreign languages, mathematics, and science. Key policy on bilingual education began to take shape starting with the 1964 Civil Rights Act, a landmark antidiscrimination law, and later with the 1968 Bilingual Education Act (Title VII of the Elementary and Secondary Education Act). However, while this latter piece of legislation provided funding for the support of language minorities, it did not provide any guidelines for instructional intervention (Ovando, 2003).

A mandate on instructional intervention arose out of the Supreme Court case *Lau v. Nichols* (1974). Widely considered the single most important decision affecting ELLs, Supreme Court justices concluded that simply providing immigrant students equal educational treatment did not constitute equal educational opportunity, and therefore violated their civil rights (Ovando, 1977). This historic case strongly affirmed the civil rights of language minorities, had the effect of eliminating sink-or-swim submersion practices, and brought the need for bilingual education to the forefront of national discussion (Ovando, 2003).

It is important to note that while *Lau v. Nichols* set a precedent requiring schools to take affirmative steps to address the needs of ELLs, it also left open a range of programs that could fulfill such a mandate. This was clarified with the decision of *Castañeda v. Pickard* (1981), a lawsuit on the behalf of parents of Mexican students against the school district in Raymondville, Texas. Considered after *Lau* to be the second most important court case regarding ELLs, it established guidelines for determining whether or not schools were taking “appropriate action” to meet the needs of ELLs (Lyons, 1992, p. 24). Known as the “*Castañeda* test”, these specified that (a) school programs must be grounded in sound educational theory, (b) adequate resources and personnel must be provided to successfully implement those programs, and (c) programs must be producing successful results, not only in language but also in content areas such as math, science, and social studies, or else they should be abandoned or modified (Lyons, 1992; Ovando, 2003). This framework has been used for program evaluation and legislative enforcement for many years, and continues to provide the basis for supporting ELLs in secondary science classrooms.

While the 1960s and 1970s gave birth to bilingual education, the 1980s saw the inception of the English-only movement still in force today. The English-only movement represents a mostly political battle characterized by fierce opposition to bilingual education. One of the most prominent supporters of the movement was “U.S. English,” which gained momentum in 1983 (Fitzgerald, 1993). The debate that ensued revolved around immigration policy, the effectiveness of bilingual education, and language ideology. As a result of these political battles, several states have enacted legislation against using native language instruction for ELLs. Though there has also been contentious debate over bilingual program evaluation, large-scale longitudinal study and rigorous meta-analysis of extant literature has shown that language minorities benefit from

native language instruction (Greene, 1998; Ramirez, Yuen, & Ramey, 1991; Rolstad, Mahoney, & Glass, 2005; Slavin & Cheung, 2005). English-only policies demonstrate that “decisions concerning the use of language in the classroom are frequently not based on findings related to best practice in education,” and that “such decisions are often made on political rather than educational grounds” (Rollnick, 2000, p. 93).

The political nature of bilingual education makes it important to consider the current context of immigration and language policy when examining students’ native language (L1) use in science classrooms. Researchers have argued that such politicization highlights the importance of basic research in bilingual education from psycholinguistic and cognitive perspectives (August & Hakuta, 1997). Overall, empirical investigation in older students’ L1 use in science learning will fulfill this need for basic research and help close gaps in the current knowledge base. Furthermore, the increasing relevance of immigration and language policy highlight a particularly urgent need for such work.

The Science Achievement of English Language Learners

During the 2012-13 school year, about 4.4 million public school students were designated as ELLs, representing about 9.2 percent of the student population (Kena et al., 2015). The majority of ELLs are represented by students of Hispanic origin, who have been the largest student-minority group since the 1990s, and are growing much faster than the nation as a whole (Chapa, 2006).

One measure of ELL achievement in science is given by the National Assessment of Educational Progress (NAEP), which measures nationally representative performance on various subjects. For the 2015 assessment in science, a nationally representative sample of about 237,300

students were assessed in physical, life, and Earth and space sciences in the 4th, 8th, and 12th grade (U.S. Department of Education, 2015, see Table 2.1).

Comparison with 2009 results shows some positive signs, including statistically significant improvement amongst ELLs in grades 4 and 8, and narrowing achievement gaps between ELLs and non-ELLs (U.S. Department of Education, 2015). However, trends remain largely unchanged: Students designated as ELLs performed worse than every other group as categorized by race, family income, or disability status. Importantly, there is widening disparity at the secondary level, and ELL students in grade 12 did not show statistically significant improvement when compared to 2009 results (U.S. Department of Education, 2015).

It is important to point out that some researchers have questioned the validity of using such standardized tests to assess ELLs on linguistic and cultural grounds (Butler, Stevens, & Castellon, 2007; Kieffer, Lesaux, Rivera, & Francis, 2009; Solano-Flores, & Nelson-Barber, 2001). For example, the linguistic demands standardized assessments may prevent an accurate assessment of science content knowledge. However, given such wide disparities in their achievement, it is more conservative to assume that these results do reflect significant underachievement in science. As a result, improving the science education of ELLs presents a particularly urgent area of needed research.

Table 2.1

Results from the 2015 Science NAEP

Student characteristic	Grade 4			Grade 8			Grade 12		
	Average scale score	At or above <i>Basic</i>	At or above <i>Proficient</i>	Average scale score	At or above <i>Basic</i>	At or above <i>Proficient</i>	Average scale score	At or above <i>Basic</i>	At or above <i>Proficient</i>
Total	154	76	38	154	68	34	150	60	22
White	166	88	47	166	82	47	160	72	27
Black	133	54	11	132	41	12	125	30	4
Hispanic	139	62	14	140	52	18	136	44	9
Asian/Pacific Islander	167	86	45	164	79	47	166	74	36
American Indian/Alaska Native	139	62	17	139	52	16	135	42	13
Student with Disability	131	53	18	124	34	11	124	29	9
English Language Learner	121	41	9	110	19	2	105	14	2

Note. Results are reported on a standardized scale (range: 0-300, $\mu = 150$, $\sigma = 35$). Attainment of *Basic* and *Proficient* achievement levels are reported as percentages. More information can be found at http://nces.ed.gov/nationsreportcard/tdw/analysis/describing_achiev.asp

The Science Education of English Language Learners

Early reviews on the science education of ELLs were first to highlight a need for further research on student L1 use in secondary science. Rollnick (2000) noted that the role of language has become an increasingly important consideration when discussing science learning. Her review described a shift away from skills-based acquisition to building understanding through authentic practice. A larger review by Okhee Lee (2005) found growing support for capitalizing on bilingual students' extant linguistic and cultural resources for science learning. A consistent finding throughout her review was the need to provide spaces in which different discourses could come together in the science classroom (Lee, 2005). These findings laid a general foundation for more explicit support of L1 usage today.

More recently, research has focused on the integration of content and language instruction to support ELLs in science instruction. This is generally articulated as the development of ELLs' language and literacy skills while engaging in authentic inquiry-based practices (Lee, Quinn, & Valdez, 2013; Llosa et al., 2016). Sizeable intervention studies conducted in grades K-6 provide evidence supporting content and language integration (August et al., 2014; Lara-Alecio et al., 2012, Llosa et al., 2016; Maerten-Rivera, Ahn, Lanier, Diaz, & Lee, 2016; Zweip & Straits, 2013). All of these studies except one (Zwiep & Straits, 2013) included some home-language supports, such as clarifications or translations of key vocabulary terms in the L1. However, these studies mostly focus on primary students and often do not cite a coherent theoretical basis to underpin recommendations of content and language integration.

It is important to note here the vast body of research supporting bilingual education in the form of transitional and dual-language programs (Baker, 2011; Greene, 1998; Ramirez, Yuen, & Ramey, 1991; Rolstad, Mahoney, & Glass, 2005; Slavin & Cheung, 2005). Such programs often

support content-area instruction in the L1 while developing students' academic English language proficiency. Although bilingual education has strong theoretical and empirical foundations at the primary level, much of this research has not been effectively translated to secondary science education.

In order to investigate L1 use amongst older students, Wu, Mensah, and Tang (under review) conducted a mixed-methods study of secondary science ELL classrooms in New York and Singapore. In New York, they examined a 9th grade introductory biology class where the dominant L1 was Spanish. In Singapore, they examined three 7th grade general science classes where the dominant L1 was Chinese. In both contexts, students were recent immigrants with low English proficiency. They found that the L1 was frequently used for learning scientific content based on observations, teacher and student interviews, and student survey data. However, L1 use was seen by some students as a hindrance to the acquisition of English. They suggest that these findings reflect a *content-language tension* between competing goals of content learning and language acquisition.

Mason (1988) first described this as a *didactic tension* between the form and substance of what is being taught. For ELLs, at issue is whether content understanding forms a basis for acquiring the language of science, or whether learning scientific English provides the tools necessary for content learning. There is some evidence that overemphasis on explicit instruction of scientific English can be problematic (Bruna, Vann, & Escudero, 2007). Some researchers advocate for a content-first approach, which prioritizes the learning of science content in order to provide a conceptual basis for the acquisition of scientific language (Brown & Ryoo, 2008; Brown & Spang 2008; Lee, Quinn, & Valdes, 2013; Quinn, Lee, & Valdés, 2012). On the other hand, the complexity and nuances of scientific language have been used as a rationale for the

direct targeting language objectives (Snow, 2010; Wong Fillmore & Snow, 2000). This encompasses explicit language instruction geared specifically towards ELLs, including vocabulary instruction and the teaching of scientific discourse features. Overall, how much emphasis to place on direct language instruction rather than acquisition through practice is still considered an outstanding question in the field.

A cognitive science perspective may help answer questions about content learning and language use. The assessment of bilingual knowledge organization examines underlying content and concepts that may be shared across languages. Concurrent assessment of language development could help clarify the relationships between content learning and language development. Such an approach has been largely neglected in current research in ELL science education and would provide valuable insight into how language use may influence classroom learning. In the next chapter, I provide an overview of relevant literature concerning bilingual cognition.

Bilingual Cognition

Bilingual cognition research is informed by studies which use imaging techniques or verbal tasks to study brain function. This chapter reviews areas relevant to L1 use in science learning, including the extent of separation between language systems in terms of neural representation and the organization of lexical, semantic, and conceptual systems. I additionally review research in knowledge networking and conceptual organization in science education. Bridging these two areas provides a methodological basis for investigating bilingual students in science education.

The Convergence of Language Systems in Bilingual Cognition

Of particular interest is the extent of integration and separation of language systems in bilinguals. This is because understanding cross-language interaction could help inform on the use of multiple languages in learning science. In the extreme case of separation, learning in one language would show little to no transfer to the other language. In the extreme case of integration, what one learns in one language would be fully accessible in the other. Overall, support has shifted from a separation of language systems to an interacting system where the degree of interaction is mediated by factors such as language proficiency, age of acquisition, and second language (L2) exposure. There is strong evidence showing increasing language proficiency results in greater cognitive overlap and interaction, referred to as *convergence*.

Background. Early hypotheses about the organization of multiple languages were drawn from studies of bilingual aphasics (Paradis, 1983). In many cases, patients suffering from aphasia due to brain injury or surgery would experience differential loss between languages (April & Tse, 1977). Cases where only one language was significantly impacted suggested distinct neurological organization of languages. Differential patterns of recovery, where one language recovered faster than the other, also lent support to this perspective. While these studies spurred research seeking to clarify the nature of this separation, they were confounded by aphasic patients who experienced deficits in both languages or had differential levels of language proficiency in either language.

Support for the separation of language organization also came from studies that used electrostimulation techniques to map language sites on the brain. Often, these studies were performed in conjunction with brain surgery in the treatment of epilepsy. Ojemann and Whitaker (1978) used electrostimulation on two bilinguals and examined the resulting interference on the

naming of objects in either language. It was found that stimulation at some sites resulted in interference of both languages, while other sites would result in interference in only one of the two languages. These results show both distinct *and* overlapping cortical representation of the second language. The authors also point out that “each patient's second language [...] seems to be represented in a wider area of cortex than the patient's primary language” and use this to suggest that increased language proficiency results in a more compact neurological representation of that language (Ojemann & Whitaker, 1978, pp. 412). In this way, Ojemann and Whitaker hypothesize convergence early on in the debate over language separation.

Evidence from functional imaging studies. The advent of functional imaging marked a great advance in the ability to clarify this debate. Imaging methods such as positron emission tomography (PET), functional magnetic resonance imaging (fMRI), and electroencephalography (EEG) have been used in conjunction with bilingual language tasks to determine the localization of dual languages.

Dehaene and colleagues performed an fMRI study on moderately proficient late French-English bilinguals (Dehaene et al. 1997). Scans were taken while participants listened to native and second language audio recordings. Consistent with previous findings, the authors report strong activation of the left temporal lobe (LTL) for both the L1 and L2. Second language scans, however, revealed greater inter-subject variability than the native language. These findings detailed by fMRI neuroimaging methods reflect a general pattern found in other imaging studies: L2 activation in general still shows LTL activation, but with a wider distribution of overall activation including increased activity in the right hemisphere (Chee, Hon, Lee, & Soon, 2001; Marian et al., 2007; Marian, Spivey, & Hirsh, 2003). Moreover, there is mounting evidence to

support that this variation in L2 activation is mediated by language proficiency and age of acquisition.

Chee and colleagues compared Chinese-English bilinguals in Singapore using fMRI during a semantic task (Chee, Hon, Lee, & Soon, 2001). One group comprised of native Singaporeans exposed to both languages before the age of five who were more proficient in English. The second group comprised of native Chinese who were exposed to English after the age of 12 and were more proficient in Mandarin Chinese. These two groups were examined because of the differences in proficiency between their two languages as well as their differing ages of acquisition. It was found that participants with lower L2 proficiency showed more distributed neurological representation. While this does not isolate the effect of language proficiency from age of acquisition, there is consistent evidence that language proficiency is more important (Abutalebi, Cappa, & Perani, 2001, 2009).

While there is growing evidence of the convergent neurological function associated with L2 development, a variety of research has revealed potentially confounding results. For example, some studies have not found such differentiation between early and late bilinguals (Chee, Tan, & Thiel, 1999). Other studies have revealed that language proficiency may not only affect localization, but also the level of neural activity in general (Chee et al., 2001). Higher levels of activation mediated by lower language proficiency on any particular task may confound interpretation of results seeking to compare participants of varying age of acquisition. Additionally, one study examining L1 activation during an L2 task suggests that unconscious translation may mediate second language comprehension (Thierry & Wu, 2007). The activation of L1 during an L2 task may lead to incorrect interpretation of language localization and may be a problem especially for lower proficiency participants.

Different aspects of linguistic processing are likely to be differentially shared. Neurological imaging studies suggest semantic processing may be especially shared (Illes et al., 1999). This seems reasonable given that languages usually differ in aspects of phonology, syntax, and morphology, but may access a unified conceptual network underlying semantic processing.

Next, I review evidence from studies that use behavioral measures on linguistic tasks to probe the degree of separation or interaction between dual languages. Evidence from this domain also supports that increased language proficiency results in a higher degree of interaction between languages, especially in semantic processing.

Evidence from psycholinguistic studies. Similar to the field of cognitive neuroscience, psycholinguistic studies were conducted to determine whether bilinguals accessed shared or independent language systems. Here, it has been important to not only distinguish factors such as language proficiency and age of acquisition, but also distinguish linguistic-cognitive constructs such as semantic and syntactical knowledge.

Early on, studies supporting independent language systems provided fodder for initial debate. Scarborough, Gerard, and Cortese (1984) examined lexical access by asking participants to identify non-target language words as if they were non-words. For example, if a participant were an English/Spanish bilingual, they would classify Spanish words as non-words when reading from a list of English words and non-words. It was found that bilinguals were able to process words in a language-specific manner without interference or priming from a second language. However, these results may reflect surface level executive processing associated with language-specific orthographies (Francis, 1999). Thus, orthographical information affecting

lexical access may function independently of each other, but this does not support the full independence of dual language processing.

In a similar study, Gerard and Scarborough (1989) investigated priming effects using a lexical-decision task where participants looked for words in a target language. It was found that non-cognate translations (translation equivalents which differ in spelling) did not result in facilitation during the task, but cognates (words with similar spelling) or homographic non-cognates (words with identical spellings but differing meanings) did. The authors use these findings to support that languages are represented independently in separate lexicons. However, similar to the study above, this seems to be principally related to orthographic information, and does not necessarily indicate fully independent language systems (Francis, 1999). For this reason, distinguishing levels of linguistic knowledge is important in determining cognitive overlap of language systems. Certain aspects of language like orthography, syntactical information, and phonology are in general different across languages and may be processed more independently.

Semantic and conceptual integration. In contrast, semantic and conceptual systems seem to be especially shared and integrated. It is appropriate to distinguish here concepts, semantic information, and lexical information. *Concepts* are the most general, and refer to “stable units of knowledge in long-term memory that represent meaningful sets of entities in the world and provide the elements out of which more complex thoughts are constructed” (Malt et al., 2016, p. 292). *Semantic information* refers to word meanings that may be considered specific subsets of concepts (Francis, 2005). More specific still, *lexical information* refers to the words themselves and includes phonological, morphological, orthographical, and syntactic information (Francis, 2005).

Various reviews of literature strongly support interaction and sharing of semantic systems across languages (Francis, 1999, 2005; French & Jacquet, 2004). Studies involving the memorization of mixed-language lists consistently show underlying semantic organization during recall as measured by priming, interference, and organization of recall (Francis, 1999; Francis, 2005). Semantic meaning learned in one language can effectively prime processing and recall in a different language (Francis, 1999, 2005). It is important to note that translations are not necessarily completely equivalent and carry with them differences such as connotation, frequency of usage, and context of acquisition (Dalrymple-Alford & Aamiry, 1970). Cross-linguistic differences must be taken into account, as variations in domains such as color, body parts, motion, and direction illustrate that words can not fully represent underlying concepts (Malt, 2013). For this reason, conceptual representations are likely to be more generally shared than semantic meanings.

Recent work is beginning to shed light on how factors such as language proficiency and age of acquisition affect this semantic sharing. For example, one study which asked participants to rank words within and across languages based on “semantic closeness” found that advanced L2 learners tended to display greater cross-language integration on the task (Dong, Gui, & Macwhinney, 2005). This supports a convergent, asymmetrical model of bilingual semantic organization, where less proficient L2 learners are highly dependent on their L1 for conceptual representation, but gradually develop direct conceptual access in their L2 (Dong, Gui, & Macwhinney, 2005).

In a study of differences based upon age of acquisition, Gathercole and Moawad (2010) examined semantic interaction between languages in early and late bilinguals. Using words with varying degrees of application (wider vs. narrower application) in either language, interaction

was measured by whether degree of application was incorrectly transferred across languages (Gathercole & Moawad, 2010). It was found that while early bilinguals showed two-way interaction of semantic structure, late bilinguals' interaction was only in the direction of L1 to L2. This suggests that when compared to late bilinguals, early bilinguals who are more fluent in both languages show more transfer of meaning between languages and that cross-language semantic interaction increases with lower age of acquisition of the second language.

Summary. Neuroimaging and psycholinguistic studies suggest that bilingual language systems display increasing overlap and interaction with lower age of acquisition and higher proficiency in both languages. For application to the ELL science classroom, a knowledge networking model of science learning (a system of mapping cross-linking of semantic content among utterances) will provide a methodological basis. This is reviewed in the next section.

Neurocognitive Model of Science Learning

Aside from advancements in understanding bilingual cognition, neurocognitive research has also provided a basis for understanding knowledge structure and organization in science learning. Such models are based on biologically plausible mechanisms of connectionist learning. A well-established paradigm of knowledge networks provides a model of cognitive organization that is based on the current understanding of neurocognitive processes (Anderson 1991, 1992, 2013; Lawson 2003). In this section I briefly review neurocognitive function, the assessment of knowledge networks, and how this may inform a methodology of studying bilinguals in science learning. One method in particular, flow-map analysis, is used in this study to assess linguistic overlap and the influence of L1 use in knowledge organization.

Networked knowledge in science learning. The basic unit of neural function is the neuron. Networks of neurons connected via synaptic transmission are currently thought to be the

structure underlying cognition and brain function (Johnson & de Haan, 2011). Models of connectionist learning are based on neural networks, where varying strengths of connections between nodes (neurons) can lead to associations of inputs and outputs (learning). The frontal lobe provides executive function which mobilizes, organizes, and manipulates information (Anderson 2014; Lawson, 2003). Together, these mechanisms provide the basis for theories that consider knowledge as instantiated and organized in a networked fashion.

Knowledge networks have seen wide application across many fields dealing with learning and educational psychology. The most common of these is in the use of concept mapping in teaching and learning, which has found broad support as an instructional aid (Nesbit & Adesope, 2006). One method, flow map analysis, allows for assessment and characterization of knowledge networks from oral narrative recall (Anderson & Demetrius, 1993). It is a way to measure individual differences in network density and conceptual organization based on sequential and recursive linkages between ideas as evidenced in oral free recall and recorded as verbal transcripts.

Flow maps provide a representation of sequential and network linkages in an individual's knowledge structure (Anderson & Demetrius, 1993). In order to create a flow map, individuals are asked to recall information about a topic, with particular emphasis placed on interrelationships between concepts. The resulting narrative is analyzed for the number of sequential and recursive linkages between concepts.

This can be performed with high reliability amongst multiple raters (Anderson & Demetrius, 1993; Anderson, Randle, & Covotsos, 2001). The extent of recursive networking provides an indication of complexity and density in an individual's knowledge structure. Well-elaborated knowledge networks show high numbers of recursive linkages, which have been

shown to correlate with other measures of learning such as inquiry lab performance and traditional multiple choice tests, supporting flow-maps as a valid assessment of the quality and robustness of an individual's knowledge network (Anderson, 2009; Anderson, Randle, & Covotsos, 2001).

This is consistent with processes of dynamic recall, with executive processes coordinating and mobilizing prior knowledge from long term memory into the working memory (Anderson, 2009; Lawson 2003; Lawson 2004). Furthermore, frontal lobe activity has been shown to provide a basis for the development of scientific reasoning skills and conceptual learning (Kwon & Lawson, 2000; Kwon, Lawson, Chung, & Kim, 2000). Given the evidence supporting flow-map analysis as valid indicators of knowledge organization and the role this plays in science learning, it provides a promising tool for assessing the organization and structure of semantic and conceptual networks of ELLs. In the next chapter, I outline the theoretical framework and present the principle research questions for this study.

Chapter III

THEORETICAL FRAMEWORK AND RESEARCH QUESTIONS

Theoretical Framework

The theoretical framework for this study has two components. The first is comprised of the language learning theories of Jim Cummins. The second component is comprised of theories of bilingual cognition and knowledge networking. Cummins (1980, 1991) was first to posit a *common underlying proficiency* for bilingual students, which assumes that skills and knowledge are transferrable between dual languages. In this paradigm, use of the L1 and L2 is characterized by interaction and interdependence. Cummins (1979, 1981) also distinguished between *cognitive academic language proficiency* (CALP) and *basic interpersonal communicative skills* (BICS). He observed that though ELLs could develop oral communicative fluency in the L2 relatively quickly, many still struggled with academic language. Taken together, his theories have been used to highlight the need for instruction in the native language while transitioning students develop their English CALP (Collier, 1987; Cummins, 2008; Hakuta, Butler, & Witt, 2000).

Research outlined in the previous chapter provides support for a theory of bilingual cognition summarized here. In terms of cognitive function, first and second languages do overlap and interact. Interaction is seen to be greatest when both languages are learned at an early age to a level of high proficiency. Evidence for this is seen in a wide range of functional imaging and psycholinguistic studies. Interaction is likely greater for semantic and conceptual information, which may not be as language-specific as orthographical, phonetic, or syntactical information. Here, this suggests that scientific concepts are more likely to be shared across languages than their surface language features.

Consequently, it is important when assessing dual language use and evidence of its cognitive structure to have a system that adequately captures both the semantic and conceptual aspects. When students freely recall knowledge, flow map analysis provides a representation of their knowledge structure that includes semantic and conceptual dimensions. High levels of recursive linking indicate more complexly organized knowledge. For this study, flow map analysis is applied in a bilingual paradigm. To my knowledge, this has not been done before. Flow maps in the L1 and L2 allow for the comparative assessment of knowledge organization in each language, providing a representation of conceptual overlap when students recall equivalent concepts and content words in both languages.

Research Questions

The purpose of this study to investigate how language use and proficiency relate to cross-language transfer and conceptual overlap by employing flow map analysis in a bilingual paradigm. The data collected inform on the validity of this approach and provide initial exploratory findings. Here are the specific research questions guiding this study:

1. What are the characteristics of in-class L1 discourse?
2. Is there any evidence of conceptual sharing/transfer when recall of information is performed in both the first and second language?
3. What relationships are observed between various measures of language use, language proficiency, academic achievement, and knowledge organization?

The first research question is intended to provide context on students' language use and proficiency in the science classroom. Observing differences in semantic organization across varying contexts of language use could contribute to a more in-depth understanding of bilingual learning as students transition to a second language. The second research question serves to test Cummins' (1980, 1991) theory of language interdependence, a longstanding paradigm in

bilingual education, using the most current and comprehensive understanding of bilingual cognition. Finally, exploring relationships amongst variables of language use, language proficiency, academic achievement, and knowledge organization can be used to evaluate the validity of the instrumentation and the theoretical framework. Addressing the third question also provides initial exploratory findings for future study.

Chapter IV

METHODOLOGY

A quantitative study was conducted in three secondary science classrooms. Institutional Review Board approvals can be found in Appendix A and B. This chapter details the context and setting, classroom treatment, instrumentation, free-recall protocol and analysis, and statistical methods of the study.

Context and Setting

The study took place during the Spring 2016 semester and lasted about four and half months. It took place at a public high school located in The Bronx, New York City. The student body at the school is about 71% Hispanic and 25% African American, while the remaining 4% is evenly distributed amongst White, Asian or Pacific Islander, Native American, and multiracial ethnicities. About 88% of students are eligible for free or reduced-price lunch, and 27% of students are designated as ELLs.

Three introductory biology classes taught by the same teacher were selected. The teacher was an African-American woman who had worked as a biological researcher for seven years before becoming a teacher. This was her fifteenth year in the classroom. The classroom teacher was explicitly supportive of L1 use in the classroom, occasionally using some Spanish phrases in her dialogue with students. However, the teacher was not fluent in Spanish and generally was unable to teach or understand classroom content in science.

Two of the classes were 9th grade, and one class was 10th grade. All three classes were geared toward the Living Environment Regents Exam, an end-of-course standardized examination required for graduation. The 10th grade class focused on similar content to the 9th grade classes but at a more challenging level. The three classes contained a total of 57 students.

Of these, 39 considered themselves Spanish-speaking bilinguals. The rest were predominantly monolingual English. Although data regarding designation as ELL status were not available, the majority of the bilingual students were fully transitioned to English and were highly proficient in English, based on observation, assessment, and survey data. These are detailed further in the results section.

Instrumentation

A researcher-created survey was used to assess self-reported language proficiency, measures of in-class language use, and beliefs and opinions regarding language use in science learning (Appendix C). The survey contained 28 questions in Likert scale format and asked students to rate their frequency of in-class L1 use and agreement with statements on how this may influence their learning.

Before the study, all survey items were presented to experts in the fields of psychological measurement, science education, and bilingual education for content validation. The survey was also reviewed by a native Spanish speaker for accuracy of translation. Surveys for non-Spanish bilingual students (Appendix D) and monolingual students (Appendix E) were also administered for consistency across students.

A science content exam was administered before and after the study to assess background knowledge and learning growth during the year. The science content exam was an excerpt of the 2015 Living Regents Exam (Appendix F). The exam is available in both Spanish and English, and these were combined to create a bilingual version of the exam consisting of 30 multiple-choice questions with English and Spanish translations presented side-by-side. Additional measures of achievement were obtained from in-class performance on multiple choice quizzes and exams. To provide an additional measure of English language proficiency, an English

assessment was administered (Appendix G). The assessment assesses basic English grammar and vocabulary.

Free-recall Protocol and Analysis

To obtain evidence of knowledge organization, students were asked to recall information learned in class using a method of semi-structured free-recall; that is, without extensive verbal prompts or structured cues, but with a predetermined and limited set of response-eliciting questions (see Appendices H-K). Students were asked to volunteer to participate in individual free-recalls, which took place throughout the semester. A total of 14 students participated, each performing an average of three free-recall sessions periodically spaced from late February to early May.

During the protocol, students were asked to freely recall knowledge of a specified topic. The topics were the cell, human impact on the environment, cellular reproduction, and human reproduction, which were all topics covered in the Living Environment curriculum and tested on the Regents exam (Appendices H-K, respectively). With each topic, a diagram or visual aid was provided to assist in recall. To create the visual aids, a web-search was used to find images aligned with in-class content. The images were then modified to have English and Spanish labels. After a brief introduction, the researcher asked three structured questions with adequate time between them to elicit recall during the protocol.

Students were asked to recall information in both English and Spanish. Recall occurred in one language, came to a conclusion, and then would occur again in the other language. On average, recall in each language lasted roughly 6-8 minutes. All instructions, questions, and materials were translated into both languages. To control for order effects, recall order (English or Spanish first) was randomly varied for each student. At times, students had difficulty recalling

science-content information in Spanish. When students asked for a translation of a word, the researcher provided it. Otherwise, the researcher provided minimal input during recalls, aside from the guiding questions. Students occasionally made use of English science words during Spanish recalls, presumably when students had difficulty discussing science in Spanish. However, the researcher generally discouraged this and it does not represent a large portion of the data.

Free-recall narratives were audio recorded, transcribed, and translated by the researcher, who is fully proficient in Spanish. Analysis followed previously established protocol (Anderson & Demetrius, 1993). Each narrative was segmented into individual discourse units, which are equivalent to independent sentences or minimally clauses. When a discourse unit refers to a previously mentioned idea or concept, a recursive linkage is drawn to the discourse unit where it first occurred.

This process is continued for the entire narrative and a sum total of recursive linkages is obtained. This total is divided by the number of discourse units to provide a *mean recursive linkage coefficient*, which provides a measure of complexity for the narrative. As mentioned earlier, this has been shown to provide a robust assessment of an individual's knowledge network and is predictive of the accuracy and amount of knowledge recalled as well as application in higher order thinking skills (Anderson, 2009; Anderson, Randle, & Covotsos, 2001; Tsai & Huang, 2002). Paired narratives from the same individual are flow-map analyzed in Figures 5.1 and 5.2.

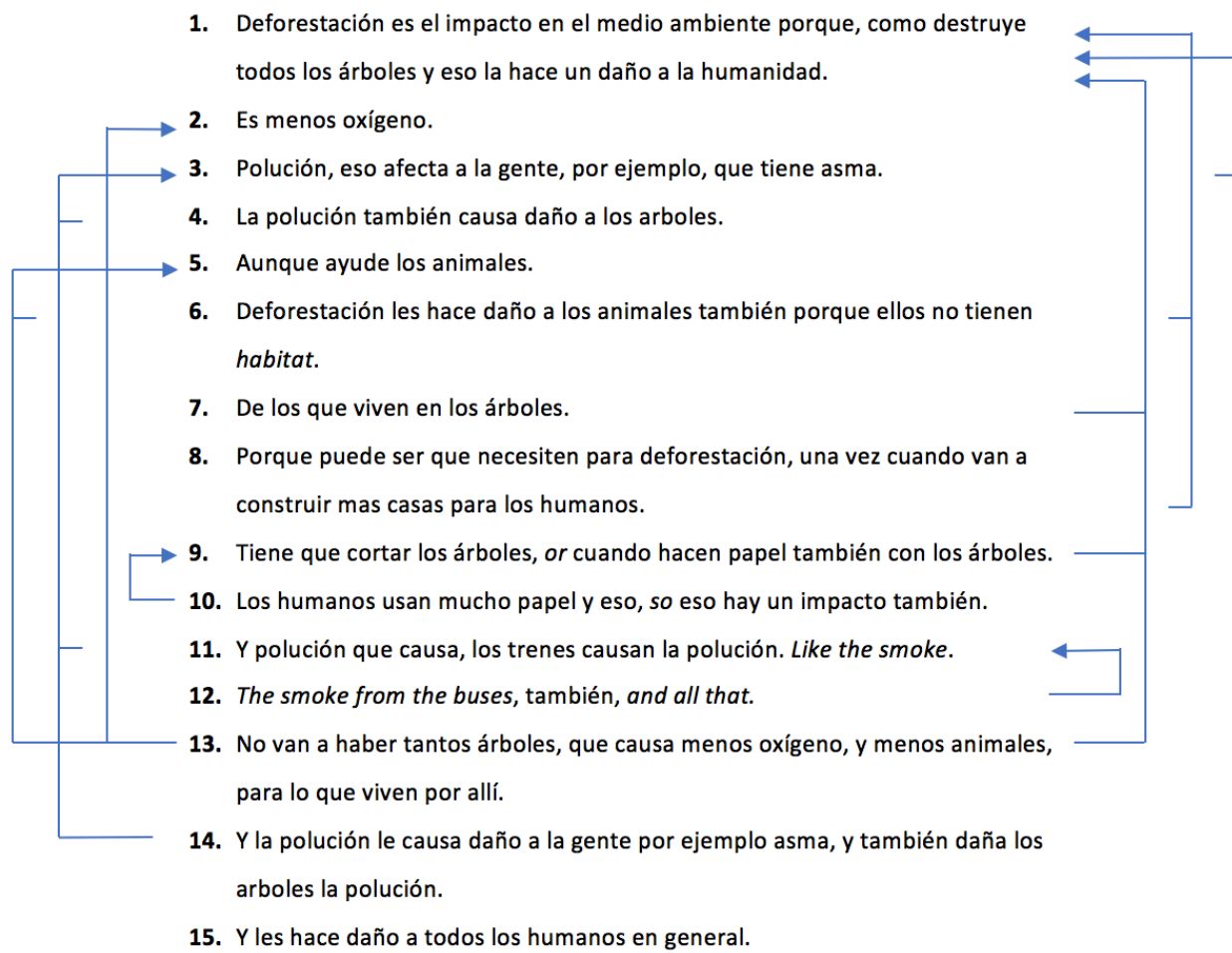


Figure 5.1. Spanish narrative with flow-map analysis. This narrative contains 15 discourse units with 15 recursive linkages. The mean recursive linkage coefficient is then $15/15 = 1$.

equivalent concepts were considered overlapping nodes. Nodes which did not appear in the other language were considered non-overlapping nodes.

The number of overlapping recursive linkages was divided by the total number of recursive linkages to provide a proportion of overlapping recursive linkages for each language. The average of this was taken to provide one overlap measurement per pair of bilingual narratives. To reiterate, separate overlap measurements were calculated for both English and Spanish narratives and revealed useful comparisons. The average of these two overlap measurements was also for paired bilingual narratives focusing on one topic. This was used for correlation analysis.

It is important to note that a similar measurement can be obtained from overlapping nodes. However, examining overlapping recursive linkages rather than nodes should characterize cross-language overlap at greater depth of cognitive processing. In contrast, examining overlapping nodes would only provide a measurement of overlap of surface-level content domains, because this would be based on individual word elements, not the semantic and conceptual relationships as indicated by cross discourse unit linkages. An example of overlapping recursive linkage analysis using the narratives in Figures 5.1 and 5.2 is provided in Table 5.1.

Table 5.1

Overlapping Recursive Linkage Analysis

Node	Recursive Linkages	
	English	Spanish
Deforestation	3	2
Trees	3	3
Pollution	3	3
Animals	1	2
Asthma	1	0
Overpopulation	1	0
Transportation	1	0
Humans	0	2
Oxygen	0	1
Paper	0	1
Smoke	0	1
<i>Total recursive linkages</i>	13	15
<i>Overlapping recursive linkages</i>	10	10
Proportion of overlapping recursive linkages	0.77	0.67
<i>Note. Average recursive linkage overlap</i>		0.72

Statistical Methods

All quantitative data were entered into SPSS for analysis. The data included survey Likert-type data, self-reported language proficiency measures, categorical variables identifying class period, group type, and gender, assessment and achievement data, and free-recall data. Based on tests for normality, the data were not sufficiently normally distributed to use parametric statistics; therefore, non-parametric tests were used. The Wilcoxon Signed-Rank test was used to compare paired bilingual free-recall data. Spearman rank-order correlation was used to determine correlation between free-recall, survey, and achievement variables. A critical level of $\alpha=0.05$ was used for all statistical tests to control for Type-1 error rates.

Summary Diagram of Methods

In order to summarize the research design, a diagram of the study's methods is presented in Figure 5.3. Three biology classes participated with thirty-nine bilingual students all-totaled. All thirty-nine students were given a demographic survey, science content exam, and English proficiency exam. From these, fourteen bilingual students were chosen for bilingual recalls to determine the overlap of recall of science content between the two languages. Wilcoxon Signed-Rank Test was computed for cross-language differences. Spearman correlation were computed for correlations between survey items and flow-map measurements.

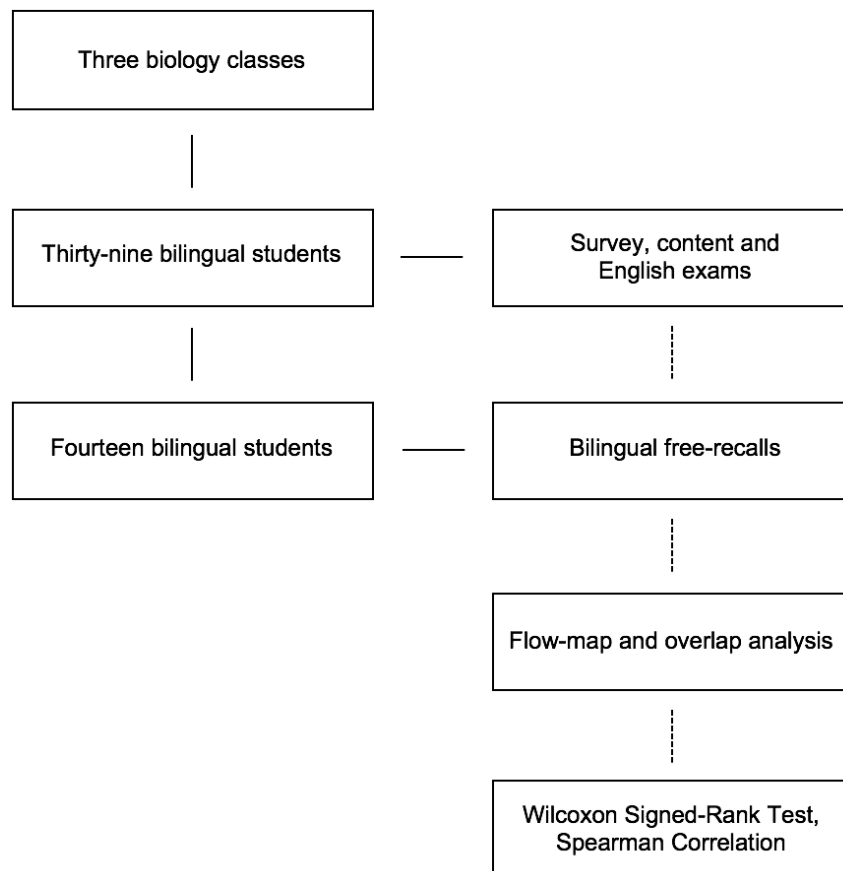


Figure 5.3. Summary diagram of research design and methods.

Chapter V

RESULTS

The results addressing each research question are presented in this chapter. For research question 1, in-class Spanish use was mainly for social rather than academic purposes, and most students were fully transitioned ELLs with high English proficiency. For research question 2, bilingual free-recalls provided evidence of conceptual overlap and transfer between languages of science content learned in-class. For research question 3, statistical analysis revealed several important relationships: Self-reported measures of English proficiency were positively correlated with knowledge organization in English as measured by mean recursive linkage coefficients. Self-reported measures of Spanish proficiency were positively correlated with conceptual overlap as measured by recursive overlap coefficients. Full details are given below according to each research question.

Research Question 1: What are the characteristics of in-class L1 discourse?

Appendix L contains full survey results, but key findings are highlighted here. Survey data from bilingual students ($n = 38$) support that in-class L1 usage was predominantly used for social chatting rather than academic purposes. Table 6.1 shows frequency data for key survey questions regarding in-class L1 use. A majority of students reported using Spanish in science class less than one a week. Similarly, students mainly disagreed with the statement “using Spanish helps me in the science classroom.” However, most students do report that their classmates “use Spanish in social chatting” at least once a week or more. When asked “How comfortable are you using English,” 35 of 38 students (92%) responded “Comfortable” or “very comfortable.” In contrast, only 22 of 38 students (58%) responded similarly for Spanish (see

Figure 6.1). On the English proficiency exam, the bilingual students achieved an average of 79%, also revealing high levels of English proficiency. This is discussed further later in this chapter.

Table 6.1

Survey Results on Language Use

Question	Never <i>or</i> Less than once a week	1-4 times a week	1-3 times day <i>or</i> More
I use Spanish in science class.	79%	11%	11%
I use Spanish to explain something to someone else.	76%	13%	10%
I use Spanish when thinking about science.	87%	8%	5%
My classmates use Spanish to explain things to each other.	66%	18%	16%
My classmates use Spanish in social chatting.	29%	21%	50%
	Strongly Disagree <i>or</i> Disagree	Neutral	Strongly Agree <i>or</i> Agree
Using Spanish helps me in the science classroom.	71%	13%	16%
Using Spanish helps me learn new words in science.	63%	21%	16%
My teacher supports the use of Spanish.	21%	42%	34%
My classmates support the use of Spanish.	13%	32%	56%
I know many science words in Spanish.	66%	18%	16%
It is easy to discuss science in Spanish.	60%	21%	18%

Note. Survey sample size was $n = 38$. Values rounded to nearest percent and may not total to 100%. Values equal to or greater than 50% are in bold.

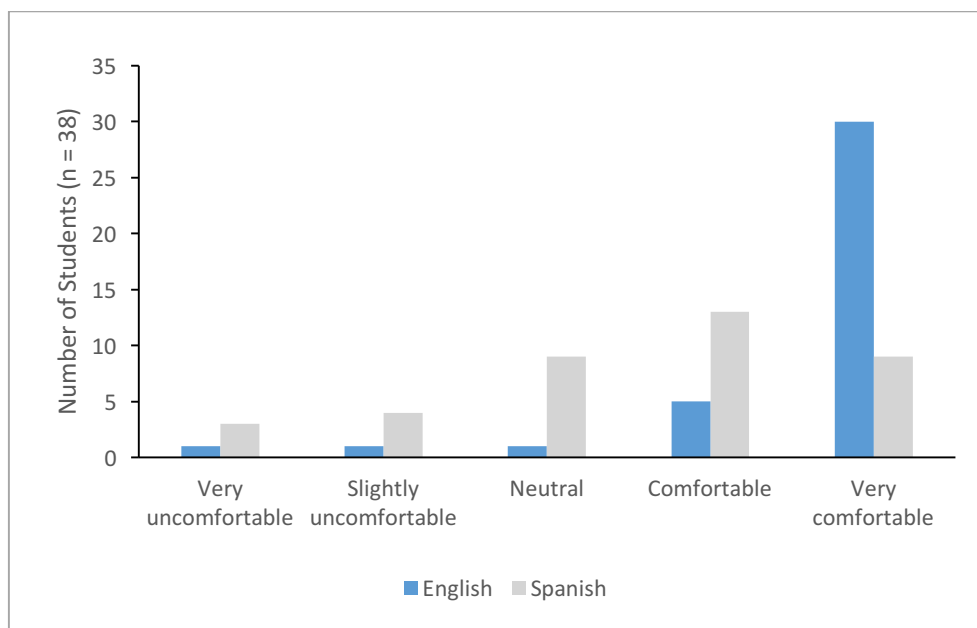


Figure 6.1. Self-reported English and Spanish Comfort Levels.

During in-class observation, students used Spanish occasionally in colloquial contexts such as in jokes or chatting. During group work focused on science content, students would default to using English. Overall, these results show a lack of significant L1 usage and suggest that participating students represent ELLs who have fully transitioned to English in the science content domain. This insight into their progress toward dual language proficiency provides a basis for the interpretation of results regarding the second and third research questions.

Research Question 2: Is there any evidence of conceptual sharing/transfer when recall of information is performed in both the first and second language?

The free-recalls focused on classroom-specific topics learned in English. Because Spanish was infrequently used for in-class learning, information recalled during Spanish free-recalls can be generally assumed to be the result of cross-language transfer. This allows for the examination of shared conceptual information that is partially the basis for Cummins' (1980, 1991) common underlying proficiency.

Fourteen students participated in bilingual free-recall sessions. The majority of students (10) participated in three sessions, while the rest participated in either two or four sessions (1 and 3 students respectively). This resulted in total of 44 free-recall narratives in each language. Most students could recall and elaborate upon information in both languages with minimal assistance from the researcher. At times, the researcher provided Spanish translations of English content words that were unfamiliar to the students. After translations were provided, the students were generally able to incorporate them freely into their Spanish recalls. In one instance, a student was unable to complete recall in Spanish due to a lack of academic Spanish proficiency resulting in 43 Spanish recalls in the final data set.

In practice, identification of overlapping nodes was straightforward and often marked by direct translation equivalents. In general, recursive linking was seen when students provided details or explanations related to a node. At times, parallel structure and similar details could be seen across students' bilingual narratives. However, there was also considerable variation in the content and form of recursive linkages.

Paired free-recalls were quantitatively analyzed for overlap using the protocol described earlier. To make statistical comparisons, averages were taken across topics for each individual, resulting in a sample size of $n = 14$. Data did not pass tests for normality so the Wilcoxon Signed-Rank test, a non-parametric method of comparing two paired groups, was used. These results are presented in Table 6.2.

Table 6.2

Free-Recall Data Averaged Across Topics

	English (n=14)		Spanish (n=14)		Wilcoxon Signed- Rank Test
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>p</i>
Discourse Units	21.9	7.1	17.1	4.2	0.021 [*]
Mean Recursive Linkage Coefficient	1.02	0.17	0.97	0.18	0.221
Nodes	7.0	2.6	6.1	1.6	0.152
Proportion Overlapping Recursive Linkages	0.67	0.19	0.76	0.15	0.084

Note. * $p < .05$, two-tailed.

Comparison of Length and Complexity

English free-recalls were significantly longer than Spanish free-recalls based on number of discourse units ($p = .021$). However, mean recursive linkage coefficients were not significantly different ($p = .221$), indicating similar levels of complexity in both languages.

Overlap Analysis

English free-recalls had a higher average number of nodes (7.05) than Spanish free-recalls (6.14); however, this difference did not reach statistical significance ($p = .152$). When averaged across languages, *node overlap* was 66.4%, indicating that about two-thirds of mentioned nodes were nodes found in both languages. *Recursive link overlap averaged across languages* was 72.4%, indicating a high degree of elaboration on the same concepts in both languages. For *recursive overlap measurements disaggregated by language*, the percent of overlapping recursive linkages was higher in Spanish (76.4%) than in English (68.4%). This difference approaches significance ($p = .084$) and suggests that recursive linking in Spanish was concentrated on shared, overlapping nodes more than in English.

Node Maps

Overlapping nodes and recursive linkages can be graphically displayed to provide an intuitive visualization and summary of information. In a node map, nodes are displayed sequentially from top to bottom in order of appearance in a set of bilingual narratives. The nodes in the center are overlapping nodes mentioned in both languages. The nodes offset to the sides are non-overlapping. The size of each node (as measured by area) is proportional to the number of recursive linkages connected to that node. For overlapping nodes, the average of recursive linkages across both languages is taken.

When viewing the node map, larger nodes immediately indicate ideas or concepts with greater amounts of elaboration, recall, and organization. Nodes found in the middle column suggest which ideas or concepts are more shared across both languages. The sizes of these overlapping nodes indicate the degree of sharing. In contrast, nodes offset to the sides immediately indicate ideas or concepts confined to only one language's recall. This suggests a stronger association between these nodes and that particular language. Finally, a comparison of the number of recursive linkages at the bottom allows for a rough estimate of the degree of overlap for each language. In Figure 6.2, the student's English recall displayed greater overlap than the Spanish recall, which displayed greater breadth in terms of nodes and recursive linkages.

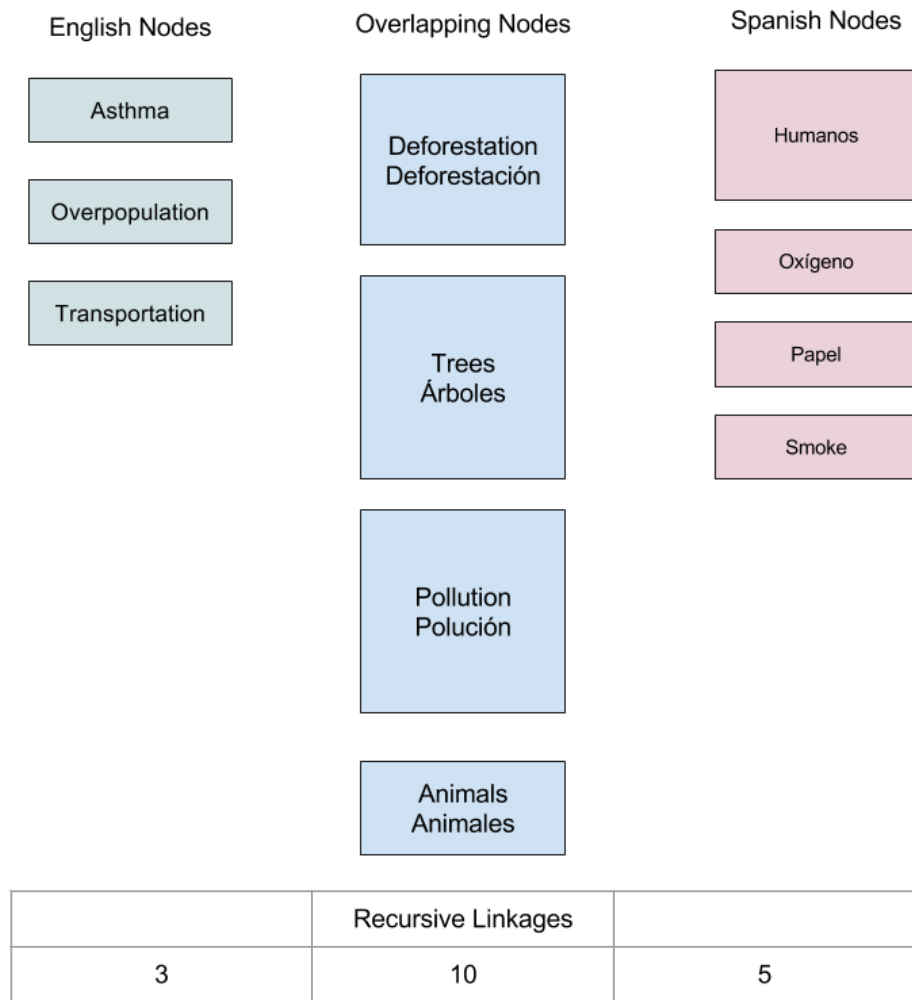


Figure 6.2 – *Node Map*. English, Spanish, and overlapping nodes from a pair of bilingual recalls. The size of each node is proportional to the number of recursive linkages represented. The number of recursive linkages for overlapping nodes are an average across both languages.

Overall, bilingual free-recalls provided evidence of recall of knowledge in both languages. Given that in-class Spanish usage was low for most students, Spanish recall should represent access to knowledge learned in English, a form of transfer. Students elaborated upon scientific concepts in Spanish with minimal assistance from the researcher. English recalls were

significantly longer; however, mean recursive linkage coefficients were not significantly different across languages, suggesting similar levels of organizational complexity.

Research Question 3: What relationships are observed between various measures of language use, language proficiency, academic achievement, and knowledge organization?

Although sample size was limited, evidence of some important relationships was found. English comfort level was positively correlated with knowledge organization in English, as measured by English mean recursive linkage coefficients averaged across topics (Spearman's $\rho = .54$, $p = .047$, $n = 14$). Self-reported English proficiency showed a similar relationship with knowledge organization in English (Spearman's $\rho = .53$, $p = .052$, $n = 14$). The average mean recursive linkage coefficients for English and Spanish narratives were positively correlated (Spearman's $\rho = .60$, $p = .022$, $n = 14$). Importantly, narrative complexity in English or Spanish were not correlated with the science content pre-test or English proficiency exams. This is further discussed later in this chapter. Additionally, Spanish narrative complexity was not correlated with Spanish comfort level, proficiency, or age of acquisition. A selected summary of correlations is presented in Table 6.3.

Table 6.3

Spearman Correlations with Narrative Complexity

Variable	n	1	2	3	4	5
1. Science Content Exam	38	-				
2. English Proficiency (self-reported)	38	-.04	-			
3. English Comfort Level	38	-.01	.33*	-		
4. Spanish Comfort Level	38	-.33*	-.18	-.31 [‡]	-	
5. English Narrative Complexity	14	.18	.53 [†]	.54*	-.30	-
6. Spanish Narrative Complexity	14	-.21	.43	.38	-.12	.60*

Note. * $p < .05$, [†] $p = .052$ [‡] $p = .055$, two-tailed.

Free-recall Overlap

As described earlier, the *recursive overlap coefficient* reflects the proportion of recursive linkages with nodes mentioned in both languages and is taken as an *average* across languages. It quantifies elaboration on ideas shared across languages during free-recall. Inversely, it also describes elaboration on ideas recalled in only one language.

Recursive overlap was positively correlated with self-reported Spanish proficiency (Spearman's $\rho = .51$, $p = .062$, $n = 14$), approaching statistical significance. Conversely, recursive overlap was negatively correlated with starting age of Spanish acquisition (Spearman's $\rho = -.53$, $p = .050$, $n = 14$). Briefly stated, students who began learning Spanish at an earlier age with stronger Spanish proficiency displayed greater dual language overlapping elaboration in narratives.

Several survey questions were found to be strongly correlated with recursive overlap. Agreement with “I know many science words in Spanish” was strongly correlated with recursive overlap (Spearman's $\rho = .84$, $p < .001$, $n = 14$). Conversely, questions related to classmates' use of Spanish to help each other such as “My classmates use Spanish to help each other” were negatively correlated with recursive overlap (Spearman's $\rho = -.73$, $p < .01$, $n = 14$). Table 6.4 provides a summary of correlations.

Table 6.4

Spearman Correlations with Recursive Overlap

Variable	n	1	2	3	4
1. Starting age of Spanish acquisition	38	-			
2. "I know many science words in Spanish"	38	-.45**	-		
3. "My classmates use Spanish to help each other"	38	.34*	-.26	-	
4. "My classmates use Spanish to explain things to each other."	38	.33*	-.12	.80***	-
5. Recursive Overlap ^a	14	-.53 [†]	.81***	-.73**	-.61*

Note. ^aRecursive Overlap refers to proportion overlapping recursive linkages averaged across languages and topics. * $p < .05$, ** $p < .01$, *** $p < .001$, [†] $p = .050$, (two-tailed).

It is important to note here that average mean recursive linkage coefficients, obtained with the flow map analyses of cross-sentence linking, in either English or Spanish were not substantially correlated with recursive overlap. However, a strong positive relationship for Spanish was seen when examining individual data that was not aggregated by topic. That is, when looking at all Spanish recalls ($n = 43$), mean recursive linkage coefficients showed a strong positive relationship with recursive overlap (Spearman's $\rho = .60$, $p < .001$, $n = 43$). English recalls did not show such a strong relationship (Spearman's $\rho = .25$, $p = .110$, $n = 43$). While the lack of independent observations prevents statistical inference, this does provide some evidence that narratives with high recursive density in Spanish show greater overlap. More data would be needed to investigate this further.

English Proficiency Exam

Although self-reported English comfort level and proficiency on pre-surveys were positively correlated with recursive density in English narratives (Table 6.3), the English proficiency exam was not (Spearman's $\rho = -.09$, $p = .773$, $n = 14$). This may due to the distribution of student results, which showed strong ceiling effects (Figure 6.3). The exam did

not differentiate students very well, making it difficult to observe latent relationships. Moreover, this may be why the English proficiency exam has no correlation with self-reported English proficiency (Spearman's $\rho = .09$, $p = .595$, $n = 36$) or comfort level (Spearman's $\rho = .19$, $p = .280$, $n = 36$). Most students self-reported very high proficiency and comfort levels in English resulting in little differentiation.

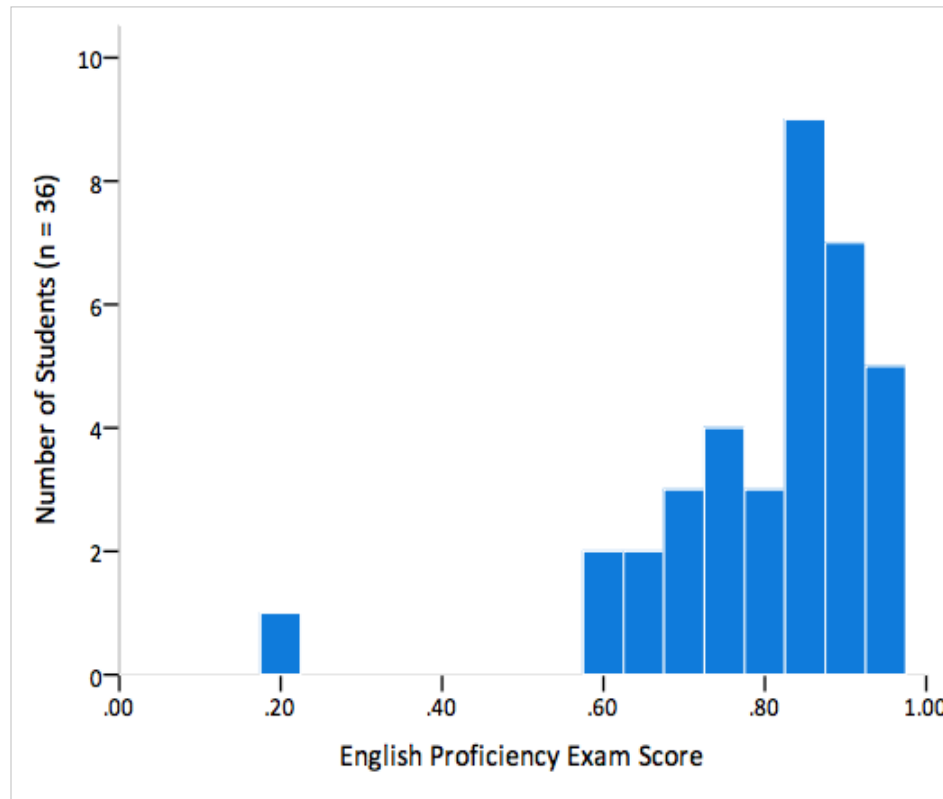


Figure 6.3. English Proficiency Exam Distribution. The exam contained 40 questions. The mean score was a 79% with a standard deviation was .14. The range was [.2-.95].

Science Content Exam

As mentioned earlier, narrative complexity in English or Spanish were not correlated with the science content pre-test (Table 6.3). The aggregation of free-recall data for statistical testing resulted in a limited sample size ($n = 14$). This likely made it difficult to observe latent relationships between science background knowledge and measures of recall complexity or

overlap. The most salient observation was a strong negative relationship between performance on the science content exam and reported Spanish proficiency (Spearman's $\rho = -.44$, $p < .01$, $n = 37$). Students with strong Spanish backgrounds showed lower background knowledge in science, in spite of the bilingual format of the exam. Conversely, top performing students on the pre-test tended to report low Spanish proficiency.

Summary

Survey responses and classroom observation support the view that students in this study were generally proficient in English. In-class, Spanish was more frequently used in social contexts rather than academic learning. Forty-four paired bilingual recalls were conducted. Bilingual narratives displayed similar levels of organizational complexity, despite English recalls being longer in terms of discourse length. Students with high self-reported English proficiency and comfort displayed more complexly organized recall in English, but this relationship was not observed in the parallel Spanish measurements. Overlap analysis revealed a high degree of elaboration on the same concepts in both languages, providing evidence of conceptual transfer across languages. Students with higher Spanish proficiency displayed higher elaboration on overlapping concepts.

Chapter VI

DISCUSSION

The characterization of the students in this study as fully-transitioned ELLs deserves closer attention here. According to survey data, most of the study participants began learning English at a young age well before the study took place. Extensive background data was not collected, and represents a limitation of the study. However, a sample of five students participated in a focus group interview at the conclusion of the study. These students described being reclassified into mainstream classrooms and losing designation as ELLs after one to three years.

Their narratives mirror findings from larger studies of ELL reclassification. Slama (2014) and Thompson (2015) show that on average, students are reclassified within 3 years and 80% of students transition out of ELL status within six years. Reclassification within 4-7 years seems to align with estimates of the time necessary to develop academic English proficiency (Hakuta et al., 2000; Slama, 2014; Thompson 2015). After being reclassified, students tend to perform better than non-reclassified ELLs (Hill, Weston, & Hayes, 2014; Slama, 2014). However, reclassified students often still struggle academically and lag significantly behind non-ELL peers (Slama, 2014).

In this study, students took a science content pre-test and post-test. The raw mean on the pre-test given mid-year was 33% ($n = 37$). The raw mean on the post-test was 37% ($n = 17$). Not all students participated in the post-test, and because it was given at the end of the year, student fatigue was a potential factor. However, these results seem to suggest that the students still face some academic difficulty in science, in spite of oral proficiency in English.

Menken and Kleyn (2010), in a study of secondary ELLs in New York City, find that such students exhibit social oral bilingual fluency, but struggle in academic areas. They suggest that subtractive bilingualism, the emphasis on rapidly acquiring oral English at the expense of developing academic skills in the native language, as a potential contributor. In contrast, the students in this study were orally bilingual with greater academic strength in English, but still seemed to struggle academically. It is not clear how the students' reclassification may have influenced their academic trajectories. Future research focusing on students with stronger academic proficiency in their native language combined with more extensive collection of background and demographic variables could help resolve this.

Bilingual Recalls

The bilingual recalls represent the elaboration of scientific knowledge on a particular topic in both languages. Recall structure is thought to reflect both the dynamic recall process and the organization of underlying knowledge (Anderson, 1992, 2009). The recall process is influenced by the visual and verbal cues provided. During the protocol, the visual and verbal prompts were kept consistent across languages, controlling for their influence the structure of recalls.

Language Dependent Knowledge Access

Students' free-recalls showed average mean recursive linkage coefficients of 1.02 in English and 0.97 in Spanish. Given previous findings, this can be considered to be average levels of complexity for 9th and 10th grade biology students in an urban high school (Bischoff & Anderson, 1998). English recalls were significantly longer than Spanish in terms discourse units, yet both exhibited similar levels of organizational complexity. This may reflect students' greater access to scientific knowledge when using English.

In psycholinguistic studies, increased fluency in a language generally translates into faster, more direct access to conceptual information in that language (Dufour & Kroll, 1995). However, there is also the matter of distinguishing “what they know” and “how well they know it”. At early ages, differences have been found between bilinguals’ home-related and academic vocabularies (Bialystok, Luk, Peets, & Yang, 2010). These differences seem to be dependent on exposure, and suggest that exposure plays an important role in determining strength and size of vocabulary. Here, it is likely that students received greater exposure to English for academic science vocabulary at later ages possibly contributing to the observed differences in discourse length. Furthermore, because all in-class instruction was in English, Spanish was not a significant part of the academic discourse. This also likely contributed to the observed language differences in knowledge access.

Aside from the number of discourse units, English recalls also had a higher average number of nodes, but this difference did not reach statistical significance. Such a difference would suggest language-specific access to more scientific knowledge. It was also found that recursive linking in Spanish was more concentrated on overlapping nodes than in English. In a way, Spanish narratives were subsumed by their counterpart English narratives, which displayed greater breadth of content and lower overlapping elaboration.

Executive Functioning across Languages

Recursive linking for English and Spanish recalls were positively correlated, and overall averages were not significantly different. Because recursive linking is largely dependent on frontal lobe executive functioning (Anderson, 2009, 2011; Anderson, Mangels, & Furman, 2006), this finding suggests consistent executive function in both languages as assessed by flow-map analysis. This is consistent with a view of executive function where it plays a top-down role

in controlling and selecting attention between languages (Bialystok, 2007). According to Fodor (1990), propositional structures and relations underpin thought. While these propositional structures and relations are language-like, they are fundamentally characteristic of thought in general and are not tied to any particular language. This could also explain the consistency in organizational structure of recall across languages.

Underlying Knowledge Structures

Bilingual narratives often exhibited parallel structure in their narratives. Students would give similar examples, explanations, and details for content items in both languages. How parallel structure of recall is influenced by underlying knowledge structures, apart from the nature of the visual and verbal cues, is an outstanding question. Research often refers to second languages as “parasitic.” That is, the less fluent language is seen to depend on the system and structure of the more fluent language, usually through unconscious translation (Gathercole & Moawad, 2010; Pavlenko, 2009; Thierry & Wu, 2007). For many students in this study, it is possible that Spanish as the weaker academic language exhibited such a dependence on English during recall. While recall order was randomly varied to limit language-specific order effects, recalled scientific knowledge was likely to be more strongly associated with English. It is possible that unconscious translation contributed to strong parallel structure in bilingual recalls (Thierry & Wu, 2007). If this is the case, this would limit the inferences made from cross-language narratives. Further study with students with higher Spanish-language proficiency would be helpful here.

English Proficiency and Achievement

Recursive linkage coefficients as measures of knowledge organization have been shown to correlate with various measures of higher order thinking skill and academic achievement

(Anderson, 2009; Anderson, Randle, & Covotsos, 2001). English proficiency and comfort levels were positively correlated with recursive linking for English narratives, but this was not seen in the parallel Spanish measurements. This may be reflective of a stronger relationship between English proficiency and academic achievement. There is a large body of evidence that shows English proficiency for ELLs is well-correlated with various measures of academic achievement, including science (Kieffer et al., 2009; Maerten-Rivera, Myers, Lee, & Penfield, 2010; Noble et al., 2012). However, standardized tests given in English are also assessments of language proficiency, making it difficult to distinguish language proficiency and content mastery.

In this study, the recalls focused on information learned in English rather than Spanish, and participating students had transitioned away from Spanish in academic settings. As a result, it is possible that Spanish proficiency and comfort levels were not strongly tied to underlying achievement measurements, including recursive linking during free-recalls. Although the science content pre-test or English proficiency exam failed to provide further evidence to support this, small sample size was likely a limiting factor. Future research with students with higher academic Spanish proficiency could help resolve this.

Recursive Overlap

Reported Spanish proficiency did, however, correlate with one important recall measurement – recursive overlap. Students with higher facility in Spanish showed greater recursive elaboration on the same concepts in both languages. This is what is predicted by Cummins' (1980, 1991) dual-iceberg theory of underlying skills and knowledge. That is, students with higher proficiency in Spanish should be able to access shared, underlying concepts with greater ease in that language, resulting in more overlap. Moreover, it is also reflective of bilingual convergence – that higher proficiency in both language contributes to greater overlap in

neurological language representation and semantic access (Frances, 2005; Abutalebi, Cappa, & Perani, 2001, 2009). These results align well with current neurological and cognitive theory and provide further evidence of methodological validity.

English proficiency did not correlate with recursive overlap. This, however, is expected if there is asymmetric dominance of English in the science content domain for these students. If the difference between English and Spanish academic proficiency is sufficiently large, changes in English proficiency level would have an attenuated effect on access to shared knowledge. As a result, the extent of recursive overlap would be more dependent on proficiency in the weaker language.

Chapter VII

CONCLUSION

The results of this study demonstrate the successful application of flow-map analysis in a bilingual paradigm, representing a novel method for assessing bilingual knowledge organization in the science classroom. As an exploratory study, I have found strong, initial evidence of its validity. Survey and observation data describe bilingual students who have fully transitioned to English in science. Flow-map results suggest a greater breadth and strength of access to scientific knowledge in English. Measures that reflect executive control did not vary by language, and recursive overlap increased with proficiency in the weaker language. These findings are in line with current cognitive-linguistic theory and offer initial evidence of the method's validity.

Study Limitations and Future Research

The study did have important limitations which should be addressed in future research. Extensive data on background and demographic variables were not collected. Information regarding ELL status may help inform on how reclassification influences developments in language proficiency, knowledge organization, and achievement in science. More precise assessment of language history, such as when students immigrated or the nature of students' ESL or bilingual programs would have informed better on their language acquisition trajectory.

The small sample size limited the power of the study's statistical methods. Increasing sample size will help future research identify underlying relationships which may have been missed here. Finally, this study mainly focused on students with relatively high English proficiency, limiting generalizability to students with lower English proficiency which is characteristic of many ELL science classrooms. Future research with secondary students who are earlier in their transition would provide greater understanding across the spectrum of language

acquisition. Research from diverse levels of English proficiency would serve to better inform teachers preparing to enter science classrooms with ELLs. This would also provide further evidence on the validity of bilingual flow-map analysis.

Implications in Science Education

This study carries important implications in science education. Reclassification seems to be a primary end-goal for the large demographic of ELLs emphasized at the outset of this dissertation. By investigating reclassified ELLs, this study provides insight into students' cognitive and linguistic developments after they transition to English. Cognitively, students were able to demonstrate well-organized knowledge in both languages. Linguistically, recall was especially facilitated by high English proficiency. The transition away from Spanish and focus on English use in the classroom likely explains the limited breadth of knowledge access in Spanish when compared to English.

It will be interesting for future research to examine students who transitioned to English more slowly or maintained their Spanish in dual-language programs designed to preserve the home-language. It is possible that stronger Spanish proficiency may influence knowledge organization in both languages, which may lead to higher academic achievement.

The results from this study highlight students' ability to access underlying conceptual knowledge through both languages. It also shows the importance of students' dominant academic language in influencing recall. For ELLs in the United States, acquiring English is an important goal. Their academic and eventual marketplace success are highly dependent on their proficiency in English. However, research has shown that reclassified students still struggle in science achievement (Slama, 2014; Thompson 2015) and there was some evidence to suggest a similar trend here

based on pre-/post-test performance. However, the evidence that these students could explain their scientific understandings of the scientific topics addressed in their free recall so extensively (mean discourse units ~ 20) in both languages, English and Spanish, is notable evidence that bilingual students may have a greater capacity for scientific literacy than sometimes reported with other ways of testing, such as paper and pencil tests.

This raises the question of whether intense focus on language acquisition at the expense of content instruction is likely to address both goals of science content learning and language acquisition effectively. Competing goals of content learning and language acquisition are likely to be in tension with each other for ELLs (Wu, Mensah, & Tang, under review). This tension is exacerbated by pressures stemming from the needs of standardized testing in English, and is likely to strongly influence decision making around language usage in class. A strong theoretical understanding is necessary to guide decision making in a variety of contexts, and a flexible approach is likely to be more helpful than whole-sale policy decisions around English use.

Overall, this research contributes to a more holistic understanding of ELLs in secondary science, which span a wide range of language proficiency. It adds to the theoretical base supporting secondary science teachers with ELLs. These teachers will find themselves in diverse contexts of students' varying language proficiency and academic background knowledge. This study helps to provide a clearer picture of bilingual cognition and learning in these varying contexts by strengthening cognitive-linguistic theory underpinning bilingual education research. As an interdisciplinary effort, it represents a synthesis of research in bilingual cognition and science education, helping to bridge these two fields. This should help hopefully help address the ELL achievement gap in these classrooms. This study also provides an example of how an interdisciplinary approach may help address complex issues in education. This requires the hard

work of synthesizing of research from various fields, but in this case, I believe it has yielded rewarding results.

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APPENDIX A

Institutional Review Board Approval, Teachers College



Teachers College IRB

Approval Notification

To: Jason Wu
From: Karen Froud, IRB Chair
Subject: IRB Approval: 16-090 Protocol
Date: 12/07/2015

Please be informed that as of the date of this letter, the Institutional Review Board for the Protection of Human Subjects at Teachers College, Columbia University has given full approval to your study, entitled "*Native Language Use in Secondary Science Classrooms*," under **Expedited Review** (Category **(7) Research on individual or group characteristics or behavior**).

The approval is effective until **12/06/2016**.

The IRB Committee must be contacted if there are any changes to the protocol during this period. **Please note:** If you are planning to continue your study, a Continuing Review report must be submitted to either close the protocol or request permission to continue for another year. Please submit your report by **11/08/2016** so that the IRB has time to review and approve your report if you wish to continue your study. The IRB number assigned to your protocol is **16-090**. Feel free to contact the IRB Office (212-678-4105 or curtn@axiomeducation.com) if you have any questions.

Please note that your Consent form bears an official IRB authorization stamp. Copies of this form with the IRB stamp must be used for your research work. Further, all research recruitment materials must include the study's IRB-approved protocol number. You can retrieve a PDF copy of this approval letter as well as the stamped consent(s) and recruitment materials from the IRB Mentor site.

When your study ends, please visit the IRB Mentor site and submit the continuing review to terminate your protocol.

Best wishes for your research work.

Sincerely,

A handwritten signature in black ink, appearing to read "KFroud".

Karen Froud, Ph.D.
Associate Professor of Neuroscience & Education
IRB Chair

Attachments:

- Informed Consent Form - Final.pdf
- Informed Consent Form - Spanish - REVISED.pdf

APPENDIX B

Institutional Review Board Approval, New York City Department of Education



Research and Policy Support Group January 6, 2016

52 Chambers Street
Room 310
New York, NY 10007

Mr. Jason S Wu
7920 Lerner Hall 2920 Broadway
New York, NY 10027

Dear Mr. Wu:

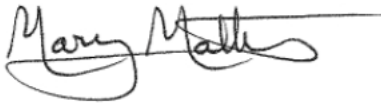
I am happy to inform you that the New York City Department of Education Institutional Review Board (NYCDOE IRB) has approved your research proposal, "Native Language Use in Secondary Science Classrooms." The NYCDOE IRB has assigned your study the file number of 1179. Please make certain that all correspondence regarding this project references this number. The IRB has determined that the study poses minimal risk to participants. The approval is for a period of one year:

Approval Date: January 6, 2016
Expiration Date: January 5, 2017

If you have any questions, please contact Dr. Mary Mattis at 212.374.3913.

Good luck with your research.

Sincerely,



Mary C. Mattis, PhD
Director, Institutional Review Board

cc: Barbara Dworkowitz

APPENDIX C

Survey for Spanish Bilingual Students

Language Survey – Bilingual Spanish *Encuesta de idioma – español/inglés*

Student Information – Información del estudiante

Name/Nombre: _____ Class/Clase: _____

Language

1. What languages do you know? Starting with the first language you learned, list the languages you know in the spaces under the heading **Language**. Under **Learning age**, write how old you were when you began learning it. Finally, in the spaces under **Proficiency Level**, rate on a scale of 1-5 for how capable you feel in each category. For example, if you feel you are very poor put 1 in the space, if you feel you are excellent put a 5 in the space, etc.

*¿Cuáles idiomas sabe usted? Empezando con su primer idioma, escriba los idiomas que sabe debajo de **Idioma**. Escriba la edad que lo aprendió en la siguiente columna. Debajo de **Nivel de competencia**, indique desde 1-5 que tan capaz se siente en cada categoría. Por ejemplo, si se siente muy básico, marque 1, si se siente excelente, marque 5 en el espacio, etc.*

No.	Language <i>Idioma</i>	Learning age <i>Edad que lo aprendió</i>	Proficiency level* <i>Nivel de competencia</i>			
			Reading <i>Lectura</i>	Writing <i>Escritura</i>	Speaking <i>Hablar</i>	Listening <i>Escuchar</i>
1						
2						
3						

*Very poor =1, Poor = 2, Fair =3 , Good = 4, Excellent = 5

*Muy básico =1, Básico = 2, Intermedio =3 , Bueno = 4, Excelente = 5

For items 2 and 3, draw a circle around the choice that you believe is best.

2. How comfortable are you using **English**?
¿Que tan cómodo se siente con el inglés?

Very uncomfortable <i>Muy incómodo</i>	Slightly uncomfortable <i>Un poco incómodo</i>	Neutral <i>Neutral</i>	Comfortable <i>Cómodo</i>	Very comfortable <i>Muy cómodo</i>
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3. How comfortable are you using **Spanish**?
 ¿Que tan cómodo se siente con el español?

Very uncomfortable <i>Muy incómodo</i>	Slightly uncomfortable <i>Un poco incómodo</i>	Neutral <i>Neutral</i>	Comfortable <i>Cómodo</i>	Very comfortable <i>Muy cómodo</i>
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The following questions have to do with the use Spanish in the science classroom. Please rate how often the following actions occur when Spanish is being used. Mark the circle that is your best choice.

Las siguientes preguntas se tratan del uso de español en la clase de ciencias. Por favor, indique la frecuencia con que realiza las siguientes acciones. Escoja la mejor opción.

	Never <i>Nunca</i>	Less than once a week <i>Menos de una vez a la semana</i>	1-4 times week <i>1-4 veces a la semana</i>	1-3 times day <i>1-3 veces al día</i>	More than 3 times a day <i>Más de 3 veces al día</i>
1. I use Spanish in science class. <i>Hablo en español en la clase de ciencias.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. I use Spanish to ask somebody to explain something to me. <i>Cuando pido una explicación a alguien lo hago en español.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. I use Spanish to ask for help. <i>Cuando pido ayuda a alguien lo hago en español.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. I use Spanish to explain something to someone else. <i>Cuando le explico algo a alguien lo hago en español.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. I use Spanish when thinking about science. <i>Cuando pienso sobre la ciencia, uso el español.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. My classmates use Spanish to help each other. <i>Cuando mis compañeros se ayudan entre si hablan en español.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. My classmates use Spanish to explain things to each other. <i>Cuando mis compañeros explican algo entre ellos lo hacen en español.</i>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<p>8. My classmates use Spanish in correcting each other.</p> <p><i>Mis compañeros hablan en español para corregirse unos a otros.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>9. My classmates use Spanish to solve problems together.</p> <p><i>En ciencias, mis compañeros hablan en español para resolver problemas.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>10. My classmates use Spanish in social chatting.</p> <p><i>Cuando estamos en grupo, mis compañeros hablan en español.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please rate your agreement with the following statements. Mark the circle that is your best choice.

Por favor, califique su acuerdo con las siguientes afirmaciones. Escoja la mejor opción.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	<i>Muy en desacuerdo</i>	<i>En desacuerdo</i>	<i>Neutral</i>	<i>De acuerdo</i>	<i>Muy de acuerdo</i>
<p>1. Using Spanish helps me in the science classroom.</p> <p><i>Hablar en español me ayuda en la clase de ciencias.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>2. Using Spanish helps me learn scientific concepts.</p> <p><i>Hablar en español me ayuda a aprender conceptos científicos.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>3. Using Spanish helps me understand ideas in science.</p> <p><i>Hablar en español me ayuda a comprender ideas científicas.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>4. Using Spanish helps me learn scientific English.</p> <p><i>Hablar en español me ayuda a aprender el inglés de científicas.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>5. Using Spanish helps me learn new words in science.</p> <p><i>Hablar en español me ayuda a aprender nuevas palabras de ciencia.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

<p>6. Using Spanish in class eventually helps me perform better on science tests.</p> <p><i>Hablar en español me ayuda eventualmente en los exámenes de ciencia.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>7. My teacher supports the use of Spanish.</p> <p><i>Mi profesor(a) apoya el uso del español.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>8. My classmates support the use of Spanish.</p> <p><i>Mis compañeros apoyan el uso del español.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>9. In my class, Spanish is seen as helpful in learning science.</p> <p><i>En mi clase, se piensa que el español puede ayudar a aprender ciencias.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>10. I like using Spanish in science class.</p> <p><i>Me gusta hablar en español en la clase de ciencias.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>11. I want to improve my Spanish.</p> <p><i>Quiero mejorar mi español.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>12. I feel comfortable using Spanish in science class.</p> <p><i>Me siento cómodo usando español en la clase.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>13. I am confident when I use Spanish in science class.</p> <p><i>Tengo confianza usando español en la clase.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>14. I know many science words in Spanish.</p> <p><i>Yo sé muchas palabras de ciencia en español.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<p>15. It is easy to discuss science in Spanish.</p> <p><i>Es fácil hablar de ciencias en español.</i></p>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX D

Survey for Non-Spanish Bilingual Students

Language Survey – Bilingual non-Spanish

Student Information

Name: _____ Class: _____

Language

1. What languages do you know? Starting with the first language you learned, list the languages you know in the spaces under the heading **Language**. Under **Learning age**, write how old you were when you began learning it. Finally, in the spaces under **Proficiency Level**, rate on a scale of 1-5 for how capable you feel in each category. For example, if you feel you are very poor put 1 in the space, if you feel you are excellent put a 5 in the space, etc.

No.	Language	Learning age	Proficiency level*			
			Reading	Writing	Speaking	Listening
1						
2						
3						

*Very poor =1, Poor = 2, Fair =3 , Good = 4, Excellent = 5

For items 2 and 3, draw a circle around the choice that you believe is best.

2. How comfortable are you using English?

Very uncomfortable	Slightly uncomfortable	Neutral	Comfortable	Very comfortable
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3. How comfortable are you using your other language (if applicable)?

Very uncomfortable	Slightly uncomfortable	Neutral	Comfortable	Very comfortable
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The following questions have to do with the use of non-English languages (that is, “another language”) in the science classroom. Please rate how often the following actions occur when another language is being used. Mark the circle that is your best choice.

	Never	Less than once a week	1-4 times week	1-3 times day	More than 3 times a day
1. I use another language in science class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. I use another language to ask somebody to explain something to me.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. I use another language to ask for help.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. I use another language to explain something to someone else.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. I use another language when thinking about science.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. My classmates use another language to help each other.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. My classmates use another language to explain things to each other.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. My classmates use another language in correcting each other.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. My classmates use another language to solve problems together.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
10. My classmates use another language in social chatting.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please rate your agreement with the following statements. Mark the circle that is your best choice.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. Using another language helps me in the science classroom.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. Using another language helps me learn scientific concepts.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. Using another language helps me understand ideas in science.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. Using another language helps me learn scientific English.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. Using another language helps me learn new words in science.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
6. Using another language in class eventually helps me perform better on science tests.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
7. My teacher supports the use of other languages.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
8. My classmates support the use of other languages.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
9. In my class, other languages are seen as helpful in learning science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

10. I like using other languages in science class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I want to improve in other languages.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I feel comfortable when I use another language in science class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I am confident when I use another language in science class.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I know many science words in another language.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. It is easy to discuss science in another language.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX E

Survey for Monolingual Students

Language Survey – Monolingual Students

Student Information

Name: _____ Class: _____

Language

For item 1, draw a circle around the choice that you believe is best.

1. How comfortable are you using English?

Very uncomfortable	Slightly uncomfortable	Neutral	Comfortable	Very comfortable
--------------------	------------------------	---------	-------------	------------------

The following questions have to do with the use of non-English languages (that is, “another language”) in the science classroom. Please rate how often the following actions occur when another language is being used. Mark the circle that is your best choice.

	Never	Less than once a week	1-4 times week	1-3 times day	More than 3 times a day
1. My classmates use another language to help each other.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. My classmates use another language to explain things to each other.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. My classmates use another language in correcting each other.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. My classmates use another language to solve problems together.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
5. My classmates use another language in social chatting.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Please rate your agreement with the following statements. Mark the circle that is your best choice.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. My teacher supports the use of other languages.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
2. My classmates support the use of other languages.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
3. In my class, other languages are seen as helpful in learning science	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
4. I want to learn other languages.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX F

Science Content Exam

Name: _____

Date: _____

Class Period: _____

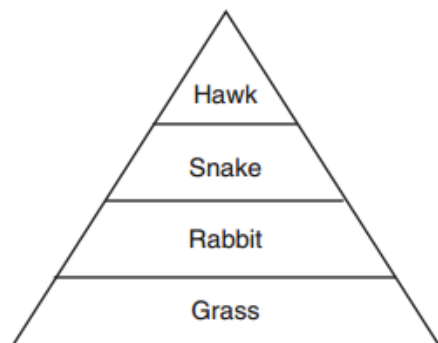
Science Content Exam

Directions (1–30): For each statement or question, record on the separate answer sheet the number of the word or expression that, of those given, best completes the statement or answers the question.

Instrucciones (1–30): Para cada enunciado o pregunta, escriba en la hoja de respuestas separada el número de la palabra o frase que, de las que se ofrecen, mejor complete el enunciado o responda a la pregunta.

- | | |
|---|---|
| <p>1 Which statement describes a situation that would reduce the stability of a forest ecosystem?</p> <ul style="list-style-type: none">(1) A fierce predator is removed from the ecosystem.(2) The number of producers remains constant in the ecosystem.(3) Organisms frequently interact within the ecosystem.(4) The energy in the ecosystem flows from the Sun. <p>2 Although the digestive system is primarily responsible for the breakdown of food, this process can be disrupted if the circulatory system malfunctions. The best explanation for this disruption is that</p> <ul style="list-style-type: none">(1) human body systems interact with each other to perform life functions(2) the circulatory system is the control center of the body(3) the digestive system and the circulatory system have many organs in common(4) the circulatory system is responsible for the coordination of life functions, including the breakdown of food <p>3 When an organism reproduces asexually, it usually has</p> <ul style="list-style-type: none">(1) only one parent, and half as much DNA as the parent(2) only one parent, and the same chromosome number as the parent(3) two parents, and twice as much DNA as either parent(4) two parents, and the same chromosome number as each parent | <p>1 ¿Qué enunciado describe una situación que reduciría la estabilidad de un ecosistema de bosques?</p> <ul style="list-style-type: none">(1) Un depredador feroz es eliminado del ecosistema.(2) La cantidad de productores permanece constante en el ecosistema.(3) Los organismos interactúan con frecuencia dentro del ecosistema.(4) La energía del ecosistema fluye del Sol. <p>2 Aunque el sistema digestivo es principalmente responsable de la descomposición de los alimentos, este proceso puede verse alterado si el sistema circulatorio no funciona bien. La mejor explicación para esta alteración es que</p> <ul style="list-style-type: none">(1) los sistemas del cuerpo humano interactúan entre sí para realizar las funciones vitales(2) el sistema circulatorio es el centro de control del cuerpo(3) el sistema digestivo y el sistema circulatorio tienen muchos órganos en común(4) el sistema circulatorio es responsable de la coordinación de las funciones vitales, entre ellas, la descomposición de los alimentos <p>3 Cuando un organismo se reproduce asexualmente, por lo general tiene</p> <ul style="list-style-type: none">(1) solo un progenitor y la mitad del ADN del progenitor(2) solo un progenitor y la misma cantidad de cromosomas que el progenitor(3) dos progenitores y el doble del ADN de cualquier progenitor(4) dos progenitores y la misma cantidad de cromosomas que cada progenitor |
|---|---|

- 4 The diagram below represents a food pyramid in an ecosystem.



The best explanation for the decrease in the amount of energy transferred to each succeeding level is that much of the energy is

- (1) consumed by predators
 - (2) released as heat
 - (3) stored within inorganic materials
 - (4) used in photosynthesis
- 5 The corn we eat today is larger and has more kernels than the corn people first grew thousands of years ago. Which process is most likely responsible for the changes that have occurred?
- (1) mitosis
 - (2) succession
 - (3) direct harvesting
 - (4) selective breeding
- 6 Which statement is correct concerning hereditary information?
- (1) A chromosome is composed of many genes.
 - (2) A gene is composed of many chromosomes.
 - (3) Each chromosome carries the same information.
 - (4) Each gene carries the same information.

- 4 El siguiente diagrama representa la pirámide alimentaria de un ecosistema.



La mejor explicación para la disminución de la cantidad de energía que se transfiere a cada nivel subsiguiente es que esa cantidad de energía es

- (1) consumida por los depredadores
 - (2) liberada en forma de calor
 - (3) almacenada en materiales inorgánicos
 - (4) usada en la fotosíntesis
- 5 El maíz que consumimos en la actualidad es más grande y tiene más granos que la mayoría del maíz que las personas cultivaban hace miles de años. ¿Qué proceso es más probablemente el principal responsable de los cambios que se han producido?
- (1) la mitosis
 - (2) la sucesión ecológica
 - (3) la cosecha directa
 - (4) la crianza selectiva
- 6 ¿Qué enunciado es correcto respecto a la información hereditaria?
- (1) Un cromosoma está compuesto por muchos genes.
 - (2) Un gen está compuesto por muchos cromosomas.
 - (3) Cada cromosoma tiene la misma información.
 - (4) Cada gen incluye la misma información.

7 Which process is most closely associated with the regulation of water loss from the leaves of trees?

- (1) digestion of water within the cytoplasm in the leaf cells of the trees
- (2) synthesis of protein by the chloroplasts in the leaf cells of the trees
- (3) movement of water through leaf openings controlled by the guard cells
- (4) absorption of nitrogen through leaf openings controlled by the guard cells

8 A mutation occurring in a human can be passed from parent to offspring when it occurs in a

- (1) lung cell, due to exposure to a toxic gas
- (2) gamete formed in the ovary
- (3) body cell undergoing mitosis
- (4) heart cell with chromosome damage

9 If the concentration of sodium is greater outside a cell than inside the cell, which process could move sodium out of the cell?

- (1) diffusion
- (2) carbohydrate synthesis
- (3) active transport
- (4) digestion

10 The basic building blocks of a protein are

- (1) glucose molecules (3) hormones
- (2) amino acids (4) fats

11 Over time, data that support the successful evolution of a species would include observations that describe

- (1) an increase in the genetic changes occurring in body cells
- (2) a decrease in the genetic variety carried in sex cells
- (3) an increase in the proportion of offspring that have favorable characteristics
- (4) a decrease in the proportion of the population that has beneficial traits

7 ¿Qué proceso está más estrechamente relacionado con la regulación de la pérdida de agua de las hojas de los árboles?

- (1) la digestión de agua dentro del citoplasma en las células de las hojas de los árboles
- (2) la síntesis de las proteínas por los cloroplastos en las células de las hojas de los árboles
- (3) el movimiento de agua a través de las aberturas de las hojas, controlado por las células guardianas
- (4) la absorción de nitrógeno a través de las aberturas de las hojas, controlada por las células guardianas

8 La mutación que se produce en un ser humano se puede transmitir del progenitor al descendiente cuando se produce en

- (1) una célula pulmonar, debido a la exposición a gases tóxicos
- (2) un gameto formado en el ovario
- (3) una célula del cuerpo que sufre mitosis
- (4) una célula cardíaca con daño en el cromosoma

9 Si la concentración de sodio es mayor fuera de la célula que dentro de la célula, ¿qué proceso podría sacar el sodio fuera de la célula?

- (1) la difusión
- (2) la síntesis de carbohidratos
- (3) el transporte activo
- (4) la digestión

10 Los bloques de construcción básicos de una proteína son

- (1) las moléculas (3) las hormonas
de glucosa
- (2) los aminoácidos (4) las grasas

11 Con el paso del tiempo, la información que apoya la evolución exitosa de una especie incluiría observaciones que describen

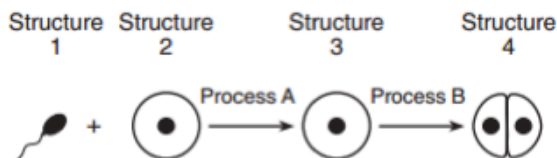
- (1) un aumento en los cambios genéticos que se producen en las células del cuerpo
- (2) una disminución en la variedad genética que transportan las células sexuales
- (3) un aumento en la proporción de descendientes que tienen características favorables
- (4) una disminución en la proporción de la población que tiene rasgos beneficiosos

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| <p>12 Caffeine is a compound found in the seeds of many different plants, such as coffee beans, cola nuts, and cacao beans (the source of chocolate). The presence of this chemical in all three types of plants suggests that these plants</p> <ul style="list-style-type: none"> (1) inherited identical mutations (2) share a common ancestry (3) were exposed to the same type of radiation in the past (4) were cloned from a caffeine plant | <p>12 La cafeína es un compuesto que se encuentra en la semilla de muchas plantas diferentes, como los granos de café, las nueces de cola y las semillas de cacao (la fuente del chocolate). La presencia de esta sustancia química en los tres tipos de plantas sugiere que estas plantas</p> <ul style="list-style-type: none"> (1) heredaron mutaciones idénticas (2) comparten una ascendencia en común (3) fueron expuestas al mismo tipo de radiación en el pasado (4) fueron clonadas de una planta de cafeína |
| <p>13 Male turkeys are birds that naturally strut and display their large tail feathers, which attracts female turkeys. This display is an example of</p> <ul style="list-style-type: none"> (1) a behavioral adaptation (2) selective breeding (3) asexual reproduction (4) a learned behavior | <p>13 Los pavos macho son aves que garbean y exhiben las grandes plumas de sus colas para atraer a los pavos hembra. Esta exhibición es un ejemplo de</p> <ul style="list-style-type: none"> (1) una adaptación conductual (2) crianza selectiva (3) reproducción asexual (4) un comportamiento aprendido |
| <p>14 A scientist at a large natural history museum has a collection of fossils that were found throughout the world. Only a few of the fossils represent species that are still alive on Earth today. One reason for this is that</p> <ul style="list-style-type: none"> (1) most of the species that have ever lived on Earth are alive today (2) most of the species that have ever lived on Earth are extinct (3) fossils of only extinct species have been found (4) species alive today will not form any fossils for future discovery by scientists | <p>14 Un científico de un museo de historia natural grande tiene una colección de fósiles que fueron encontrados en distintas partes del mundo. Solo algunos fósiles representan especies que todavía están vivas en la Tierra en la actualidad. Un motivo de esto es que</p> <ul style="list-style-type: none"> (1) la mayoría de las especies que han vivido en la Tierra viven en la actualidad (2) la mayoría de las especies que han vivido en la Tierra se extinguieron (3) solo se han encontrado fósiles de especies que se extinguieron (4) las especies que viven en la actualidad no formarán fósiles para futuros descubrimientos por parte de los científicos |
| <p>15 Which statement concerning sexual reproduction is correct?</p> <ul style="list-style-type: none"> (1) It is not necessary in order for the individual to survive. (2) The offspring are identical to the parent. (3) It is necessary in order for the individual to survive. (4) The offspring are identical to each other. | <p>15 ¿Qué enunciado sobre la reproducción sexual es correcto?</p> <ul style="list-style-type: none"> (1) No es necesaria para que el individuo sobreviva. (2) Los descendientes son idénticos al progenitor. (3) Es necesaria para que el individuo sobreviva. (4) Los descendientes son idénticos entre sí. |

16 When a paramecium, a single-celled organism, is living under stressful conditions, it sometimes switches from asexual to sexual reproduction. The main advantage when this switch occurs is that the paramecium is most likely to

- (1) produce fewer offspring
- (2) increase variation among its offspring
- (3) avoid having to find a mate
- (4) produce clones of itself

17 The diagram below represents some processes in the early development of a multicellular organism.



Which statement describing this diagram is correct?

- (1) The cell represented by structure 3 has the same genetic content as structure 2.
- (2) Process A represents the process of meiosis.
- (3) Each cell in structure 4 has the same genetic content as that in structure 3.
- (4) Processes A and B both occur in the placenta.

18 Which statement describes a function of the hormone estrogen?

- (1) It regulates the secretion of digestive enzymes.
- (2) It promotes sperm production in males.
- (3) It influences the development of adult sex characteristics.
- (4) It maintains blood sugar levels.

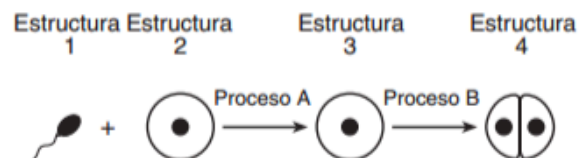
19 The primary function of the human male reproductive system is to

- (1) provide a site for fertilization
- (2) produce and transport gametes
- (3) protect and nourish the embryo
- (4) prevent urine from leaving the body

16 Cuando un paramecio, un organismo unicelular, vive bajo condiciones de estrés, a veces cambia de la reproducción asexual a la reproducción sexual. Cuando se produce este cambio, la principal ventaja es que el paramecio muy probablemente

- (1) produzca menos descendientes
- (2) aumente la variación entre sus descendientes
- (3) evite tener que encontrar una pareja
- (4) produzca clones de sí mismo

17 El siguiente diagrama representa algunos procesos en la etapa inicial del desarrollo de un organismo multicelular.



¿Cuál enunciado que describe este diagrama es correcto?

- (1) La célula que representa la estructura 3 tiene el mismo contenido genético que la estructura 2.
- (2) El proceso A representa el proceso de meiosis.
- (3) Cada célula de la estructura 4 tiene el mismo contenido genético que la de la estructura 3.
- (4) Los procesos A y B ocurren en la placenta.

18 ¿Qué enunciado describe una función de la hormona estrógeno?

- (1) Regula la secreción de las enzimas digestivas.
- (2) Promueve la producción de espermatozoides en los machos.
- (3) Influye en el desarrollo de las características sexuales en el adulto.
- (4) Mantiene los niveles de azúcar en sangre.

19 La función principal del sistema reproductivo masculino humano es

- (1) brindar un sitio para la fecundación
- (2) producir y transportar los gametos
- (3) proteger y nutrir el embrión
- (4) evitar que la orina salga del cuerpo

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| <p>20 In an embryo, the formation of many types of tissues and organs occurs as a result of the process of</p> <ul style="list-style-type: none"> (1) fertilization (2) genetic sorting (3) differentiation (4) gene recombination <p>21 Which activity would be an appropriate first step when designing an experiment?</p> <ul style="list-style-type: none"> (1) reporting a conclusion based on multiple experimental trials (2) researching the problem, using information from a variety of sources (3) creating a data table to organize experimental observations (4) repeating the experiment with a different hypothesis <p>22 Every time a child visited a cousin who has two cats, the child's eyes turned red, itched, and began to water. Then, the child began to have trouble breathing. It is most likely that the child reacted this way because</p> <ul style="list-style-type: none"> (1) normally harmless cat antigens stimulated the immune system (2) it is difficult for the respiratory system to filter cat antigens out of the inhaled air (3) cat antigens are a health hazard, since they always cause disease (4) cat antigens stop the immune system from making antibodies, so bacteria cause these responses <p>23 Shrimp that live in the cold waters off Alaska will die if introduced into warm water. One likely reason these shrimp do not survive is that enzymes in the shrimp</p> <ul style="list-style-type: none"> (1) start to replicate (2) change shape (3) are composed of fat molecules that melt (4) break down into small starch molecules | <p>20 En un embrión, la formación de muchos tipos de tejidos y órganos se produce como resultado del proceso de</p> <ul style="list-style-type: none"> (1) fecundación (2) distribución genética (3) diferenciación (4) recombinación genética <p>21 ¿Qué actividad sería un primer paso apropiado al momento de diseñar un experimento?</p> <ul style="list-style-type: none"> (1) informar una conclusión basada en varios ensayos experimentales (2) investigar el problema usando información de varias fuentes diferentes (3) crear una tabla de datos para organizar observaciones experimentales (4) repetir el experimento con una hipótesis diferente <p>22 Cada vez que un niño visitaba a un primo que tiene dos gatos, los ojos del niño se ponían rojos, le ardían y comenzaban a lagrimear. Luego, el niño comenzó a tener problemas para respirar. El motivo más probable para la reacción del niño es que</p> <ul style="list-style-type: none"> (1) los antígenos del gato, que por lo general son inofensivos, estimularon su sistema inmune (2) para el sistema respiratorio, es difícil filtrar los antígenos del gato del aire que se inhala (3) los antígenos del gato son un peligro para la salud, porque siempre causan enfermedades (4) los antígenos del gato impiden que el sistema inmune cree anticuerpos, por eso, la bacteria causa estas reacciones <p>23 Los camarones que viven en las aguas frías de Alaska morirían si se introducen en aguas cálidas. Un posible motivo por el que estos camarones no sobrevivirían es que las enzimas del camarón</p> <ul style="list-style-type: none"> (1) comienzan a replicarse (2) cambian de forma (3) están compuestas de moléculas de grasa que se derriten (4) se descomponen en pequeñas moléculas de almidón |
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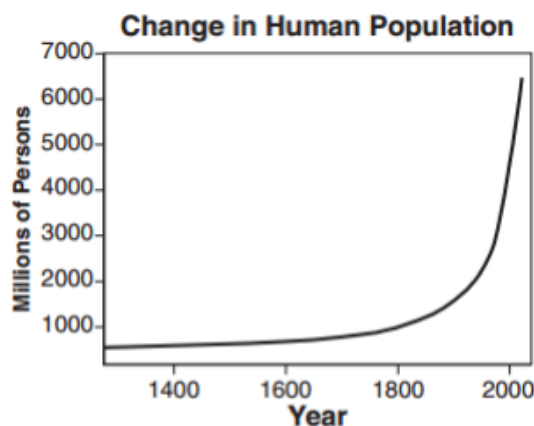
24 A DNA segment removed from neurospora (a pink mold) contained the base sequence G-T-C-C-A-T-G-C-A. A similar segment of DNA removed from neurospora that had been exposed to radiation for several hours had the base sequence G-T-C-C-A-T. This change in the base sequence is an example of

- (1) a deletion (3) a substitution
- (2) an insertion (4) a replication

25 Farmers in India have increased the harvest yield of food crops like eggplant by growing them from seeds that have been modified to produce a bacterial toxin that is harmful to pest insects. This is an example of

- (1) selective breeding of the insects
- (2) spraying an insecticide on plants
- (3) selective breeding of the eggplant
- (4) an application of biotechnology

26 The graph below shows changes in human population numbers over time.



A consequence of these changes is

- (1) an increase in the numbers and kinds of organisms worldwide
- (2) a decrease in the availability of natural resources
- (3) a decrease in deforestation due to technological improvements
- (4) an increase in biosphere stability

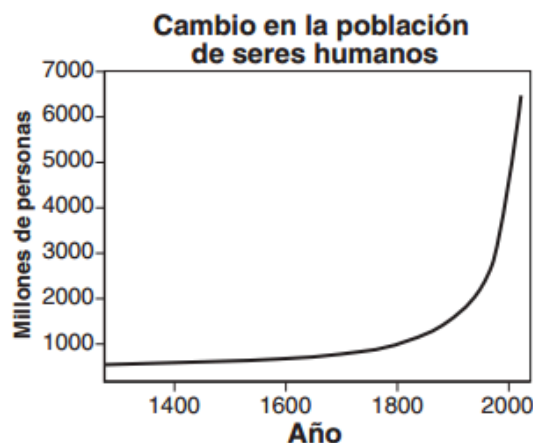
24 Un segmento de ADN extraído de una neurospora (un moho rosado) tiene la secuencia base G-T-C-C-A-T-G-C-A. Un segmento similar de ADN extraído de una neurospora, que había estado expuesta a la radiación por varias horas, tenía la secuencia base G-T-C-C-A-T. Este cambio en la secuencia base es un ejemplo de

- (1) una eliminación (3) una sustitución
- (2) una inserción (4) una replicación

25 Agricultores de la India han aumentado el rendimiento de cultivos de alimentos, como la berenjena, sembrando semillas modificadas para producir una toxina de bacteria que es dañina para los insectos que son peste. Este es un ejemplo de

- (1) crianza selectiva de insectos
- (2) rociado de un insecticida en las plantas
- (3) crianza selectiva de berenjenas
- (4) una aplicación de la biotecnología

26 El siguiente gráfico muestra los cambios en las cantidades de la población humana a lo largo del tiempo.



Una consecuencia de estos cambios es

- (1) un aumento en las cantidades y los tipos de organismos a nivel mundial
- (2) una disminución en la disponibilidad de recursos naturales
- (3) una disminución en la deforestación debido a mejoras tecnológicas
- (4) un aumento en la estabilidad de la biosfera

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| <p>27 In the fall, some farmers plow the remains of corn plants into the ground. This activity contributes most directly to the</p> <ul style="list-style-type: none"> (1) increase in the biodiversity of their fields (2) depletion of nonrenewable resources (3) destruction of natural habitats (4) recycling of organic matter <p>28 A person usually experiences small variations in body temperature over a 24-hour period. These variations in temperature are an example of</p> <ul style="list-style-type: none"> (1) an immune response (2) genetic differences between individuals (3) an adaptation to global warming (4) dynamic equilibrium <p>29 Fossil fuels have been used for years as a source of energy. Even though there are many negative issues associated with the use of fossil fuels, they continue to be used to a great extent. This is most likely because</p> <ul style="list-style-type: none"> (1) they have been commercially available as an energy source (2) there are alternatives to these types of fuels (3) they have had a positive effect on global temperatures (4) fossil fuels can be burned to produce large quantities of carbon dioxide <p>30 Sometimes, a person is born with one or more extra chromosomes in each cell. This usually results in abnormalities because the affected person has</p> <ul style="list-style-type: none"> (1) a reduced number of genes in cell nuclei (2) fewer cell mutations than a person with a normal chromosome number (3) more genes in each cell than a person with a normal chromosome number (4) less DNA in cell nuclei, but more proteins in cell mitochondria | <p>27 En el otoño, algunos agricultores aran los residuos de las plantas de maíz en el suelo. Esta actividad contribuye directamente a</p> <ul style="list-style-type: none"> (1) el aumento de la biodiversidad en sus campos (2) el agotamiento de los recursos no renovables (3) la destrucción de los hábitats naturales (4) el reciclado de materia orgánica <p>28 Una persona generalmente experimenta pequeñas variaciones en la temperatura corporal en un periodo de 24 horas. Estas variaciones en la temperatura son un ejemplo de</p> <ul style="list-style-type: none"> (1) una respuesta inmune (2) diferencias genéticas entre los individuos (3) una adaptación al calentamiento global (4) equilibrio dinámico <p>29 Los combustibles fósiles se han usado por años como una fuente de energía. Aunque hay muchas cuestiones negativas relacionadas con el uso de combustibles fósiles, su uso sigue siendo muy popular. Esto se debe más probablemente a que</p> <ul style="list-style-type: none"> (1) han estado disponibles para su comercialización como fuente de energía (2) hay alternativas para este tipo de combustibles (3) han tenido un efecto positivo en las temperaturas a nivel mundial (4) los combustibles fósiles pueden quemarse para producir grandes cantidades de dióxido de carbono <p>30 Algunas veces, una persona nace con uno o más cromosomas adicionales en cada célula. Por lo general, esto produce anomalías, porque la persona afectada tiene</p> <ul style="list-style-type: none"> (1) una cantidad reducida de genes en los núcleos de las células (2) menos mutaciones celulares que una persona con una cantidad normal de cromosomas (3) más genes en cada célula que una persona con una cantidad normal de cromosomas (4) menos ADN en los núcleos de las células, pero más proteínas en la mitocondria de la célula |
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APPENDIX G

English Proficiency Exam

English Proficiency Exam

Name _____ Date _____ Period _____

Questions 1-12 – Choose the correct answer and write its number (1, 2, 3, 4) in the parentheses ().

1. Does Catherine have an untidy room? Yes, she _____.
1) didn't
2) don't
3) does
4) did ()

2. Most of us loathe dishonest people, _____ we?
1) don't
2) won't
3) can't
4) shouldn't ()

3. The weekend was boring. Rosie _____ do anything because of the horrible weather.
1) no
2) didn't
3) won't
4) can't ()

4. Please, lock the door as you leave because I _____ to work now.
1) go
2) going
3) am going
4) have gone ()

5. Maylene's friends speak only two languages but she _____ four.
1) am speaking
2) be speaking
3) speaks
4) spoke ()

6. Annie _____ from Ireland but her parents hail from England.
 1) was coming
 2) is coming
 3) will come
 4) comes ()
7. The book I _____ about astrology was extremely fascinating.
 1) am reading
 2) was reading
 3) will be reading
 4) has been reading ()
8. Yu Lin met a friend while she _____ her shopping so they decided to go on a shopping spree.
 1) is doing
 2) was doing
 3) has done
 4) already done ()
9. I paid for my things when I _____ someone call my name.
 1) hear
 2) heard
 3) hearing
 4) have heard ()
10. A banker is like _____ man who lends you _____ umbrella when _____ weather is fine but takes it away from you when it rains.
 1) - , the, an
 2) a, an, the
 3) the, an, -
 4) an, -,the ()

11. _____ accountant is _____ man who is hired to explain that you didn't make _____ money you think you did.
 1) The, an, -
 2) -, the, an
 3) An, a, the
 4) A, the, an ()
12. "We _____ a celebration party for workers after the completion of the project tomorrow!" I declared.
 1) will hold
 2) holding
 3) was holding
 4) held ()

Questions 13-17 – Fill in each blank with the correct preposition. Each word may only be used once.

in	on	for	at	of	into	by
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13. What's the reason _____ the change in schedule?
14. Who's the man _____ the picture? He looks so familiar.
15. Congratulations _____ your success. You must have burnt the midnight oil.
16. I'm reading a book _____ Dickens. It's an interesting read.
17. I divided the cake _____ three slices so that each of us could get a big piece.

Questions 18-22 – Choose the correct answer and write its number (1, 2, 3, 4) in the parentheses ().

18. Can Shari be excused? She _____ quite ill.
1) appears
2) senses
3) feels
4) thinks ()
19. Before accepting the terms, Shanmei _____ the offer very carefully since it was fairly binding.
1) considered
2) debated
3) felt
4) thought ()
20. Carol spent a long time _____ the abstract painting but still could not tell what it was all about.
1) studying
2) thinking
3) seeming
4) working ()
21. Mother scolded, "Please _____ on the unwise things you have done!"
1) consider
2) reflect
3) question
4) perceive ()
22. The director _____ Ginger's presence by nodding his head and briefly smiling at her.
1) believed
2) considered
3) favoured
4) acknowledged ()

Questions 26-35 – Choose the correct answer and write its number (1, 2, 3, 4) in the parentheses ().

26. Mary _____ have a problem, she's always upset and crying.

- 1) must
- 2) can
- 3) ought
- 4) should

()

27. You absolutely _____ check the tires before you leave today.

- 1) must
- 2) can
- 3) ought to
- 4) should

()

28. People _____ to drive more carefully on the roads to avoid accidents.

- 1) must
- 2) do
- 3) can
- 4) ought

()

29. If it's more convenient for you, I _____ pick you up tomorrow night.

- 1) must
- 2) can
- 3) ought
- 4) should

()

30. We wanted to go to the opera, but we _____ get tickets so we went to the cinema instead.

- 1) must
- 2) can
- 3) could
- 4) couldn't

()

31. I know a man _____ keeps bees because he sells honey to the market.
1) who
2) which
3) whom
4) whose ()
32. A mobile phone is a telephone _____ you can carry around with you.
1) who
2) which
3) whom
4) what ()
33. Everyone _____ wanted a ticket to the concert has bought one by now.
1) which
2) whom
3) who
4) that ()
34. George is a boy on _____ you can always depend for help.
1) whom
2) what
3) that
4) which ()
35. Can you tell me _____ the time is? It seems so late.
1) who
2) what
3) which
4) that ()

Questions 36-40 – Read the following passage. For each item, choose the word that is closest in meaning to the underlined word in the passage and write its number (1, 2, 3, or 4) in the parentheses ().

Sunflowers date back to ancient times. Seeds found in North American clay date back nearly 3000 years. The sunflower often follows the sun and this (36) characteristic is how it got its name.

Early American natives used the sunflower long before corn and beans were brought to America. They ate the seeds, ground the small kernels into flour, (37) extracted oil from the seeds for their hair, and used the seeds, flower petals, and pollen to make dyes for face paint, cloths, and baskets. In Peru, the Aztecs (38) worshipped sunflowers. They placed sunflower images made of gold in their temples and crowned princesses with the (39) bright yellow flowers.

Sunflowers made their way to Europe in the early 1500s. They were used for (40) gifts carried by Spanish settlers returning home. The Great Russian ruler Peter the Great liked sunflowers so much that when he saw them in Holland, he took some seeds back to Russia.

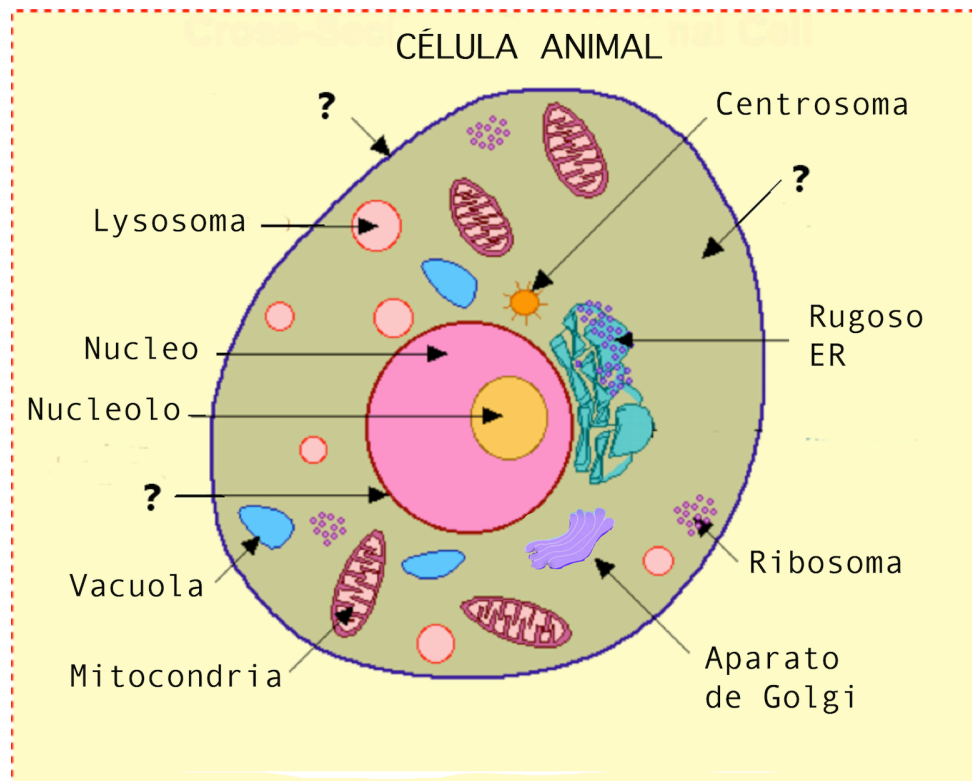
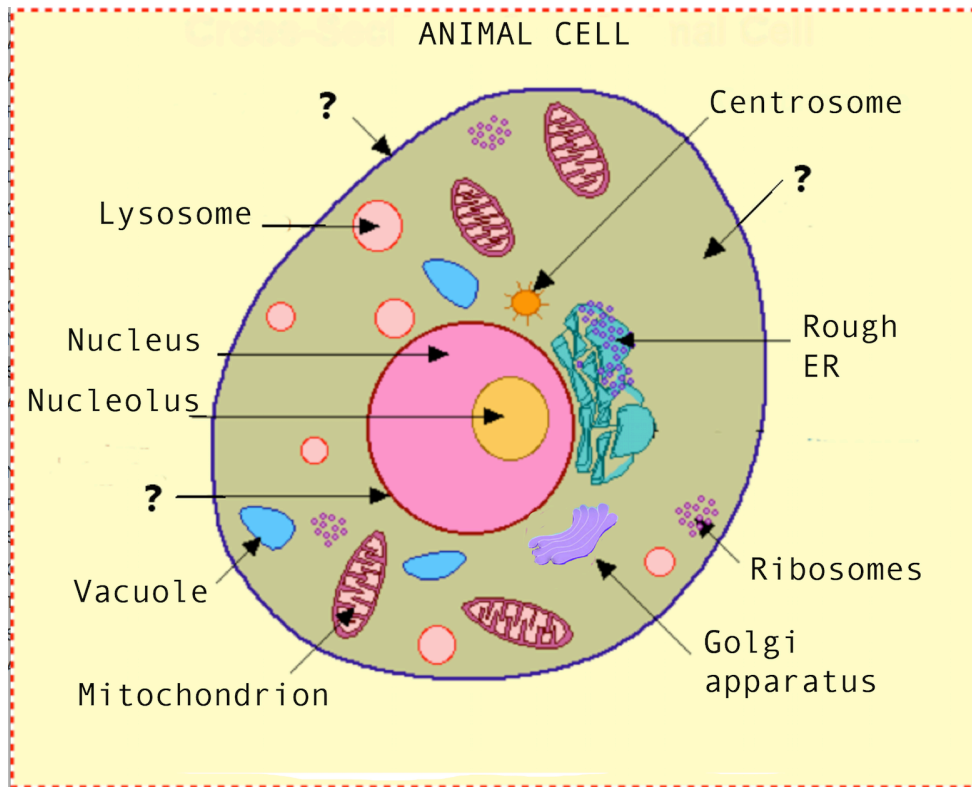
- | | |
|---|---|
| <p>36. 1) thing
2) tact
3) trait
4) tale ()</p> | <p>39. 1) dazzling
2) dull
3) colourful
4) awful ()</p> |
| <p>37. 1) objected
2) obtained
3) ordained
4) orientate ()</p> | <p>40. 1) protection
2) decorations
3) payments
4) presents ()</p> |
| <p>38. 1) revered
2) reversed
3) reserved
4) released ()</p> | |

APPENDIX H

Free-Recall Protocol and Materials – The Cell

Interview Protocol - Individual Student Recall	
Date: Time: Location/Setting: Interviewee(s): Research Question: <i>What is the influence of students' native language use on their science learning?</i>	
<p style="text-align: center;">Introduction</p> <ul style="list-style-type: none"> Today we are going to do an exercise that will explore your knowledge on a topic that you have recently learned from science class. I am going to show you a diagram and will ask you a few questions to guide you along. Please try to recall everything you know, and focus especially on how things are related to one another. We will be doing this exercise first in English, then in Spanish, for no more than 15 minutes each. Questions? <ul style="list-style-type: none"> Vamos a hacer un ejercicio de recordar lo que hemos aprendido en la clase de ciencia. Voy a mostrarte una diagram y hacer algunas preguntas. Trata de recordar todo lo que sabes y enfoca en como las cosas se relacionan. Vamos a hacer el ejercicio primero en ingles y despues en espanol para un maximo de 15 minutos cada idioma. Preguntas? 	Time
ENGLISH PROTOCOL	
1. This is a diagram of an animal cell, like the one you've learned about in class. Please look at the diagram and try to remember what you've learned. Tell me about these things and how they are related one another.	
<p style="text-align: center;">If student has provided substantial information:</p> <ul style="list-style-type: none"> Please look at the diagram. What else can you tell me about it? 	
<p style="text-align: center;">If student has not provided substantial information:</p> <ul style="list-style-type: none"> Please look at the labeled parts of the diagram of the cell. What can you tell me about them? What do they do? 	
<p style="text-align: center;">For all students:</p> <ul style="list-style-type: none"> Please tell me more about how do these things relate to each other? 	

SPANISH PROTOCOL	
<p>1. Este es un diagrama de la célula animal, como la que has visto en la clase. Por favor, mira a la diagrama y trata de recordar lo que has aprendido. Explicame estas cosas y como se relacionan.</p>	
<p>If student has provided substantial information:</p> <ul style="list-style-type: none"> • Por favor, mira a la diagrama. ¿Qué más me puedes decir sobre la diagrama? 	
<p>If student has not provided substantial information:</p> <ul style="list-style-type: none"> • Por favor, mira a las partes nombradas en la diagrama. ¿Qué me puedes decir sobre estas cosas? ¿Qué hacen? 	
<p>For all students:</p> <ul style="list-style-type: none"> • Por favor, explicame más sobre como se relacionan estas cosas? 	



APPENDIX I

Free-Recall Protocol and Materials – Human Impact on the Environment

HUMAN IMPACT ON THE ENVIRONMENT	
Date: Time: Location/Setting: Interviewee(s): Research Question: <i>What is the influence of students' native language use on their science learning?</i>	
<p style="text-align: center;">Introduction</p> <ul style="list-style-type: none"> Today we are going to do an exercise that will ask about your knowledge on a topic that you have recently learned from science class. I am going to show you a diagram and will ask you a few questions to guide you along. Please try to recall everything you know, and focus especially on how things are related to one another, how they work together, or what they have in common. We will be doing this exercise first in English, then in Spanish, for no more than 15 minutes each. Questions? <ul style="list-style-type: none"> Vamos a hacer un ejercicio de recordar lo que hemos aprendido en la clase de ciencia. Voy a mostrarte una diagrama y hacer algunas preguntas. Trata de recordar todo lo que sabes y enfoca en como las cosas se relacionan, como funcionan juntos, o que tienen in comun. Vamos a hacer el ejercicio primero en ingles y despues en espanol para un maximo de 15 minutos cada idioma. Preguntas? 	Time
ENGLISH PROTOCOL	
1. These are examples of impacts of humans on the environment, like the ones you've learned about in class. Please look at this list and try to remember what you've learned. Tell me everything you know about these things and how they are related one another.	
Can you tell me about any others?	
Can you tell me about why these things occur?	
Can you tell me some of the consequences of these actions?	
SPANISH PROTOCOL	
1. Estos son ejemplos de impactos de los humanos en el medio ambiente, como la que has visto en la clase. Por favor, mira a la lista y trata de recordar lo que has aprendido. Dime todo lo que sabes y como se relacionan.	
¿Me puedes decir mas de las otras?	
¿Me puedes decir por qué ocurren estas acciones?	
¿Me puedes explicar las consecuencias de estas acciones?	

Impact Of Humans On the Environment

- Deforestation
- Pollution
- Coral reef destruction
- Erosion
- Invasive species



Impacto de los humanos en el medio ambiente

- Deforestación
- Polución
- Destrucción de arrecife de coral
- Erosión
- Especies invasivas

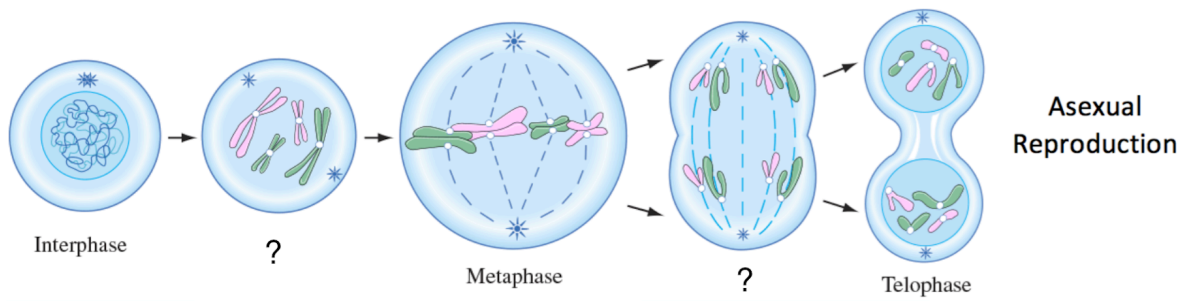


APPENDIX J

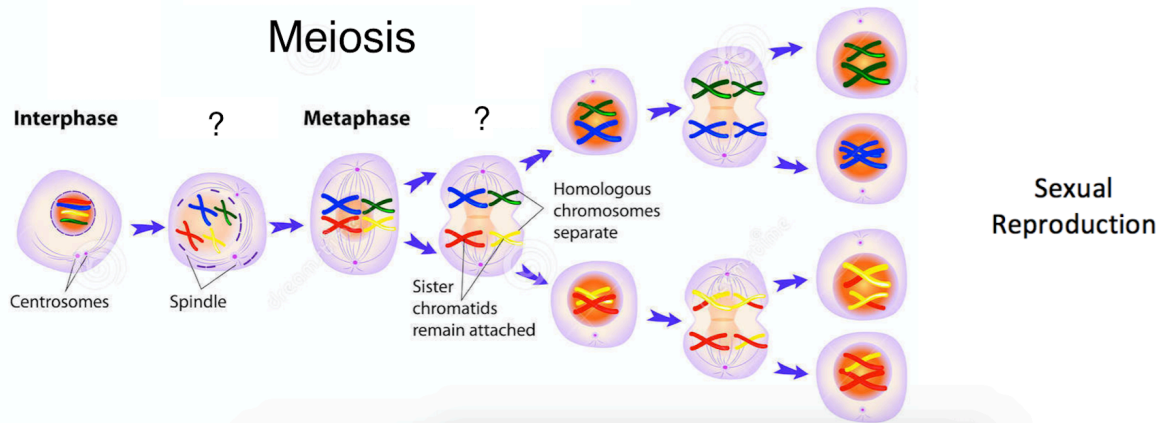
Free-Recall Protocol and Materials – Cellular Reproduction

CELLULAR REPRODUCTION	
<div style="background-color: white; color: black; padding: 2px; display: inline-block;">Copy</div> <p>Time:</p> <p>Location/Setting:</p> <p>Interviewee(s):</p> <p>Research Question: <i>What is the influence of students' native language use on their science learning?</i></p>	
<p style="text-align: center;">Introduction</p> <ul style="list-style-type: none"> Today we are going to do an exercise that will ask about your knowledge on a topic that you have recently learned from science class. I am going to show you a diagram and will ask you a few questions to guide you along. Please try to recall everything you know, and focus especially on how things are related to one another, how they work together, or what they have in common. We will be doing this exercise first in English, then in Spanish, for no more than 15 minutes each. Questions? Vamos a hacer un ejercicio de recordar lo que hemos aprendido en la clase de ciencia. Voy a mostrarte una diagrama y hacer algunas preguntas. Trata de recordar todo lo que sabes y enfoca en como las cosas se relacionan, como funcionan juntos, o que tienen in comun. Vamos a hacer el ejercicio primero en ingles y despues en espanol para un maximo de 15 minutos cada idioma. Preguntas? 	Time
ENGLISH PROTOCOL	
<p>1. These are diagrams of mitosis and meiosis, like the ones you've learned about in class. Please look at them and try to remember what you've learned. Tell me everything you know about mitosis, focusing on how things are related to one another.</p>	
<p>Can you tell me about meiosis, focusing on how things are related to one another?</p>	
<p>Can you tell me about sexual and asexual reproduction how they are related to one another.</p>	
SPANISH PROTOCOL	
<p>1. Estas son diagramas de mitosis y meiosis, como las que has visto en la clase. Piensa en lo que has aprendido. Dime todo lo que sabes sobre mitosis, enfocándose en como se relacionan las cosas.</p>	
<p>¿Me puedes explicar meiosis, enfocándose en como se relacionan las cosas?</p>	
<p>¿Me puedes explicar la reproducción sexual y asexual, enfocándose en como se relacionan las cosas?</p>	

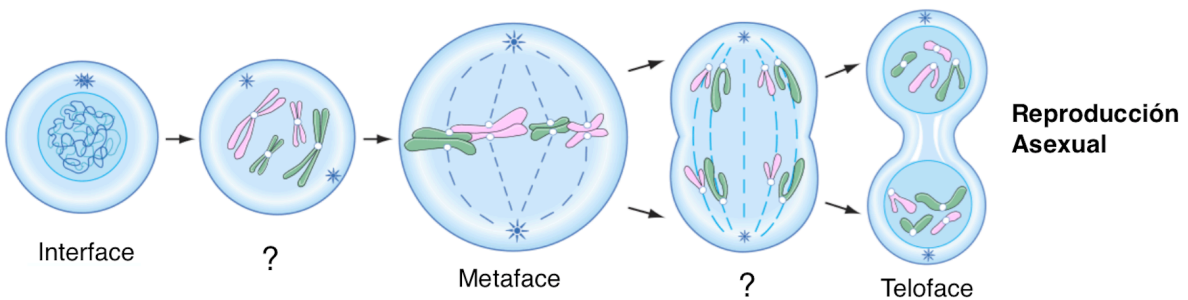
Mitosis



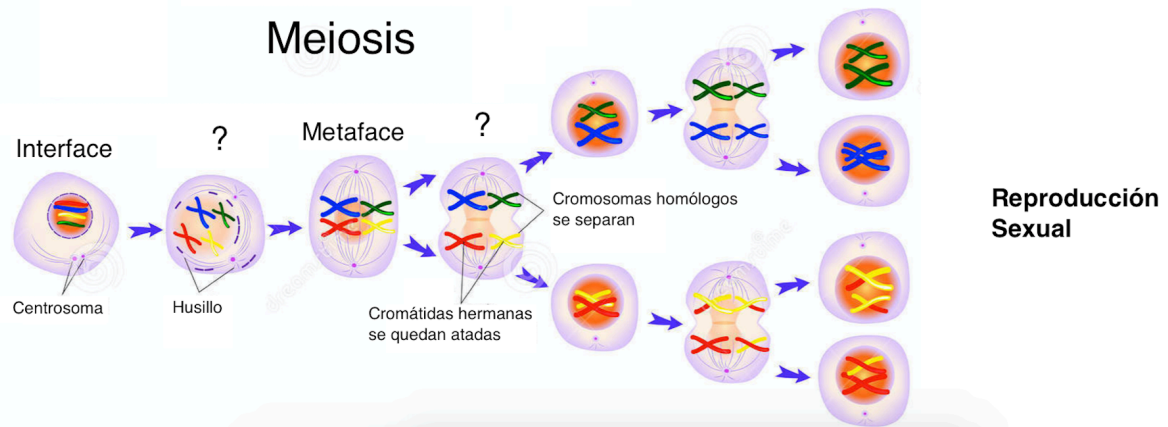
Meiosis



Mitosis



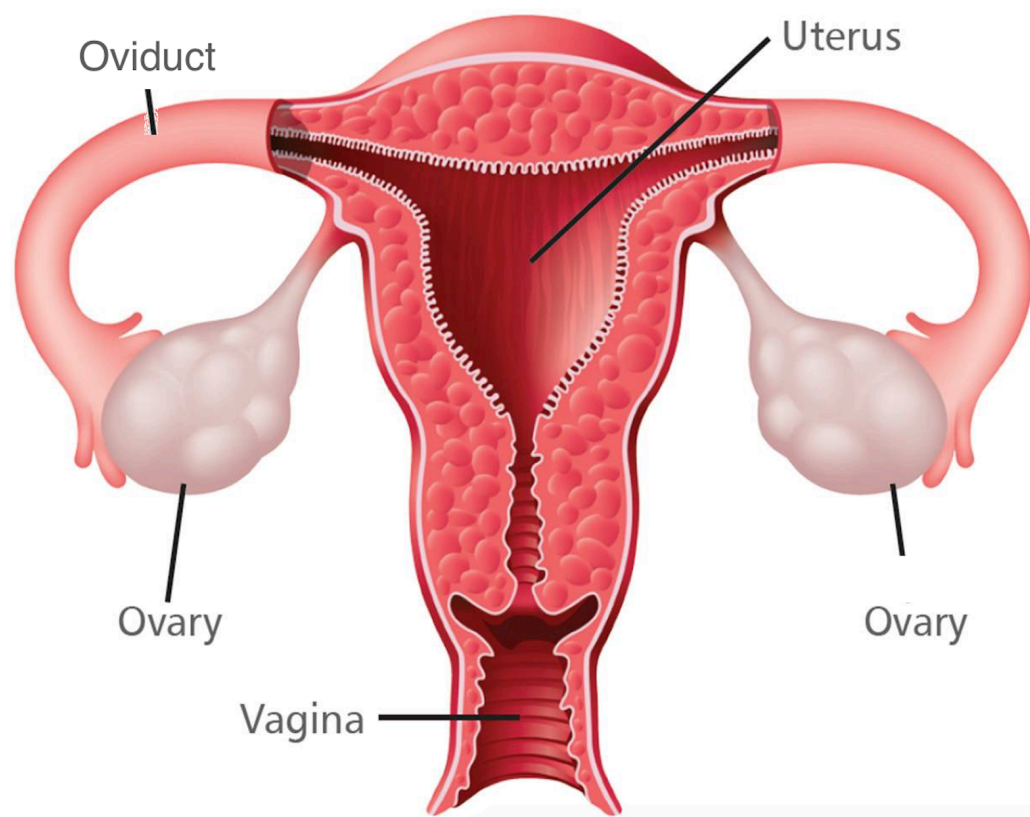
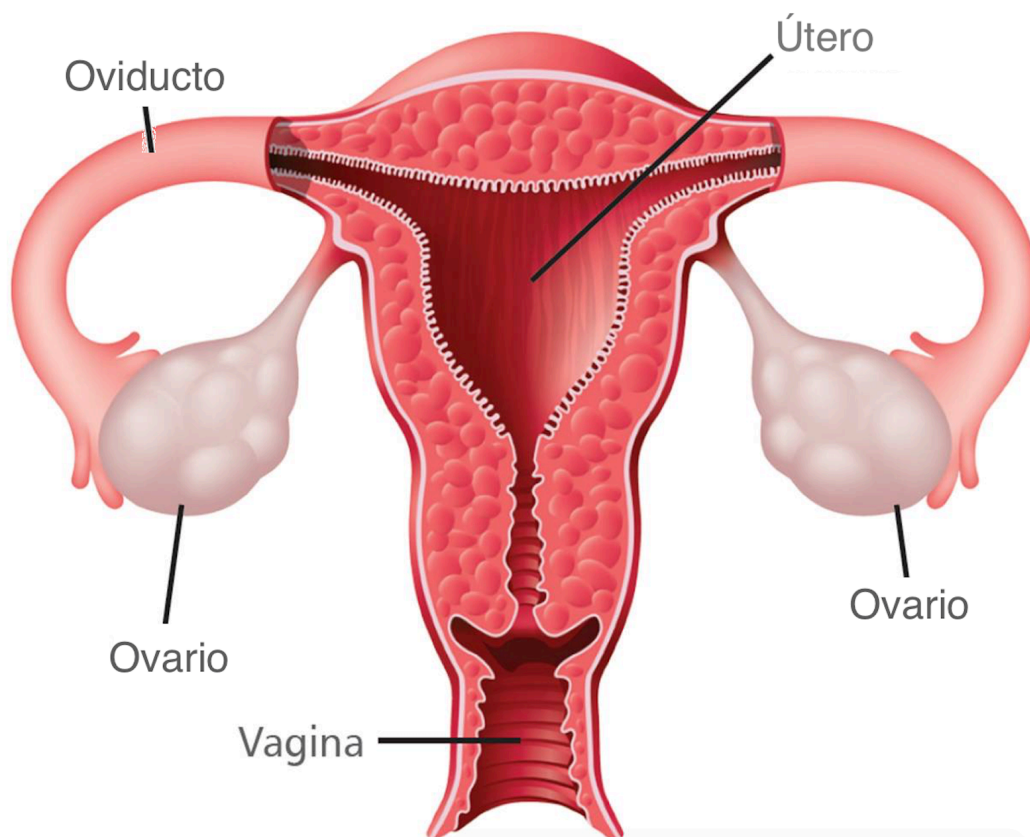
Meiosis



APPENDIX K

Free-Recall Protocol and Materials – Human Reproduction

HUMAN REPRODUCTION	
Date: Time: Location/Setting: Interviewee(s): Research Question: <i>What is the influence of students' native language use on their science learning?</i>	
<p style="text-align: center;">Introduction</p> <p>Today we are going to do an exercise that will ask about your knowledge on a topic that you have recently learned from science class.</p> <p>I am going to show you a diagram and will ask you a few questions to guide you along. Please try to recall everything you know, and focus especially on how things are related to one another, how they work together, or what they have in common.</p> <p>We will be doing this exercise first in English, then in Spanish, for no more than 15 minutes each.</p> <p>Questions?</p> <p>Vamos a hacer un ejercicio de recordar lo que hemos aprendido en la clase de ciencia. Voy a mostrarte una diagrama y hacer algunas preguntas. Trata de recordar todo lo que sabes y enfoca en como las cosas se relacionan, como funcionan juntos, o que tienen in comun.</p> <p>Vamos a hacer el ejercicio primero en ingles y despues en espanol para un maximo de 15 minutos cada idioma.</p> <p>Preguntas?</p>	Time
ENGLISH PROTOCOL	
1. This is a diagram of the female reproductive system. Please look at it and try to remember what you've learned about human reproduction. Tell me everything you know about the process of fertilization, focusing on how things are related to one another.	
Can you tell me anything else about fertilization?	
Can you tell me anything else about human reproduction?	
SPANISH PROTOCOL	
1. Esta es una diagrama del sistema reproductivo femenino. Por favor, mira a la diagrama y trata de recordar lo que aprendiste de la reproducción humana. Dime todo lo que sabes sobre el proceso de fertilización, enfocando en como todo se relaciona.	
¿Me puedes decir algo mas de fertilizacion?	
¿Me puedes decir algo mas de la reproducción humana?	



APPENDIX L

Full Survey Results

Full Survey Results

Question	Very uncomfortable	Slightly Uncomfortable	Neutral	Comfortable	Very comfortable
How comfortable are you using English?	1	1	1	5	30
How comfortable are you using Spanish?	3	4	9	13	9

	Never	Less than once a week	1-4 times week	1-3 times day	More than 3 times a day
I use Spanish in science class.	25	5	4	1	3
I use Spanish to explain something to someone else.	27	7	1	2	1
I use Spanish to ask for help.	27	5	2	2	1
I use Spanish to explain something to someone else.	19	10	5	2	2
I use Spanish when thinking about science.	27	6	3	2	0
My classmates use Spanish to help each other.	18	7	9	2	2
My classmates use Spanish to explain things to each other.	15	10	7	2	4
My classmates use Spanish in correcting each other.	18	12	7	1	0
My classmates use Spanish to solve problems together.	26	9	1	1	1
My classmates use Spanish in social chatting.	5	6	8	7	12

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Using Spanish helps me in the science classroom.	14	13	5	3	3
Using Spanish helps me learn scientific concepts.	14	9	14	1	0
Using Spanish helps me understand ideas in science	12	11	10	5	0
Using Spanish helps me learn scientific English.	13	13	8	1	3
Using Spanish helps me learn new words in science	17	7	8	6	0
Using Spanish in class eventually helps me perform better on science tests.	17	11	8	0	2
My teacher supports the use of Spanish.	5	3	16	5	8
My classmates support the use of Spanish.	5	0	12	9	12

In my class, Spanish is seen as helpful in learning science.	10	9	11	5	3
I like using Spanish in science class.	12	7	11	3	5
I want to improve my Spanish.	4	3	9	8	14
I feel comfortable using Spanish in science class.	6	6	11	11	4
I am confident when I use Spanish in science class.	8	8	12	8	2
I know many science words in Spanish.	13	12	7	5	1
It is easy to discuss science in Spanish.	13	10	8	5	2

Note. Survey sample size was n = 38. Values are provided as frequencies.